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THE BOMBAY LOCUST.

(Acridium succinctum. Linn.)

A REPORT ON THE INVESTIGATIONS OF 1903-1904.

BY

H. MAXWELL-LEFROY, M.A., F.E.S., F.Z.S.,

Entomologist to the Government of India.

AGRICULTURAL RESEARCH INSTITUTE, PUSA.

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A REPORT OF THE INVESTIGATIONS

ON

THE BOMBAY LOCUST.

By H. MAXWELL-LEFROY, M.A., F.E.S., F.Z.S.,

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PART I.

THE FORMATION AND MOVEMENTS OF LOCUST SWARMS.

First Period.—Emergence.

During September, 1903, young locusts were reported from the Panch Mahals District of the Bombay Presidency, and were found to be in the last stage prior to maturity. In October the winged locusts were found in Panch Mahals, Surat, parts of Khandeish, Baroda, Ahmedabad and Thana, in scattered localities from Bombay to Ahmedabad, mostly within 100 miles of the coast. The crop reports mention the presence of locusts in the Panch Mahals early in September, and in Ahmedabad in the third week of the same month. The reports from Baroda mention locusts from the 5th September onwards. Apparently large numbers of young locusts were to be found in Gujarat and the North Konkan during September, had search been made for them. In the Surat district, full-grown locusts were found in the long grass grown for hay. They remained concealed in this grass until they emerged during the middle of the month, when

the grass dried and was cut. During the latter half of the month, these locusts entered the crops and found ample shelter in the fields of juari, (*Andropogon sorghum*), where they fed on the leaves and ripening grain. This happened also in Broach, Panch Mahals and Kaira, as well as in the Baroda State. Immense numbers of locusts appeared, wandered aimlessly about for a time, gradually formed into swarms and moved over the country side. In the Surat District the swarms were closely watched; they moved little at first, the swarms not being compact, and did much damage to crops in some villages where they stayed for a long period. Gradually the swarms formed, moved from field to field, and finally became definite bodies of locusts whose progress from village to village could be clearly traced. The approximate area from which the locusts emerged is marked in the Map, Plate II.

Second Period.—Migration.

Late in October the swarms commenced moving in a definite direction. The migration was on the whole from north to south with a trend inland from the coast. The numerous reports from district officers, the very full evidence of the officials in Baroda State, the information furnished by the Diwan of Rajpipla State, all agree in defining a regular migration, observed by day in the movements of the swarms, or observed in the places in which swarms successively alighted in their passage through a district. The movement commenced earlier in the Northern districts, but as a whole the main movement was in progress early in November. They passed through Kaira, Baroda, Rajpipla, Broach, Surat, into Ratnagiri and Kolaba and the adjoining hilly forest regions. This continued throughout November and by the end of that month only scattered swarms remained which disappeared during December. The locusts in Eastern Khandeish appear to have pursued a similar course, their migration being south westwards into the Ghât region, over the Nasik District. Probably there were other unreported swarms which moved at this time, all apparently centering on the hilly forest Ghât region. This period

closes in December with the arrival of the swarms in the Ghât region.

The origin of these swarms admits of little doubt when the whole evidence is considered. They were hatched in the localities where they were first seen, spending the hopper stages there and only appearing when full grown, except in parts of Ahmedabad and the Panch Mahals. This statement is based on observation, and is the only inference possible from the reported facts and from investigations into the life history. The large area of grass land especially near the coast of Gujarat was probably full of small and harmless hoppers in the rains of 1903, unnoticed because they were concealed in the long grass. With the ripening of the grass, the hoppers became winged, spent their first few days there, emerged into the crops in search of food and finally packed in swarms for the migration to the Ghât region. This is fully borne out by observation of the young locusts in the rains of 1904.

It must be remembered that locusts are not invariably seen or reported, nor is there any record of their occurrence in ordinary years. The distribution of the locusts and their origin in 1903 are thus only partially known ; many localities are probably permanent breeding places, *e.g.*, places in Portuguese territory (Goa), the forests of Kanara and other parts of the Western Ghâts, without such a fact being now ascertainable. B. P. Standen, Esq., Director of Agriculture, Central Provinces, states that the locusts have been permanently in Nimar and Holkar's territory for four years ; there are doubtless other such places. A safe statement would appear to be that the main mass of locusts in 1903 was bred in Gujarat, with a contingent from Khandeish and from permanent breeding places in the Ghâts and hilly forest tracts in Western India.

The migration during November took place chiefly at night, which accounts for the somewhat mysterious manner in which locusts appeared and disappeared. Many swarms were traced for days on end and then vanished in a single night, the watchmen stating that they flew away during the night. For many nights immense numbers of locusts were seen passing

over Surat, not in swarms but singly. The air seemed to be full of locusts, whose wings glistened as they flew across the moon and then vanished. An endless stream was to be seen on moonlight nights and the movement probably continued on dark nights also. Migration for any distance during the day was rare but did occur. As a rule the limit of the day flights was a few miles. Apparently these prolonged nocturnal flights carried the locusts over long distances, bringing them eventually to their destination in the forests. There is nothing unusual in such flights, which are a feature of locust swarms.

The true migratory locust, *Acridium peregrinum*, also appeared in Gujarat after the swarms of Bombay locusts, *Acridium succintum*, had left. Kathiawar reported swarms of this true migratory locust in November, and swarms were seen alighting at places along the coast, apparently after their flight over the Gulf of Cambay. These swarms passed through the Surat District in early December, compact swarms flying by day and visible far out to sea as they approached land. The fate of these swarms is still unknown; no specimens of *Acridium peregrinum* were caught among the swarms of the Bombay locusts.

Third Period. The Winter Months.

The end of November and early December found the swarms settling in the forest regions on the Ghâts, including parts of the Kolaba, Ratnagiri, Khandeish, Nasik, Poona and Satara collectorates. These had come through Thana principally, the first swarms late in October when they settled so thickly on the trees of Bassein as to break down their branches. During late November and December they spread over the forests, an area of some three hundred miles long and forty broad. From December to March they remained in this area, feeding upon the forest trees, moving in vast swarms during the day. From Kalyan southwards through Pen, Mahableshwar, Satara, Chiplun, Kolhapur and the Northern part of the Belgaum district, locusts occurred in vast swarms and were to be seen in countless numbers along the G. I. P. and Southern Mahratta railways that run to Poona. This area is shown in Plate II.

Fourth Period.—Second Migration.

During the second half of March and the beginning of April, the outward movement from the Ghât region commenced. The movement was from the Ghât region to the interior, that is, to the North-East, East and South-East mainly. The movement to the North-East was a very large one, the swarms passing over Thana, Nasik, Poona, Khandeish and Ahmednagar; others moved eastwards over Sholapur and Bijapur, and a large movement took place over Belgaum and Hyderabad, Dharwar and Kanara. The swarms proceeding North-East penetrated to the Panch Mahals and Rajpipla, to Bhopawar in Central India, and over the Western half of the Central Provinces as far as Nagpur. They arrived in Panch Mahals in May, in Rajpipla in May and in Chota Udaipur in June. The swarms going East and South passed into Hyderabad, into Bellary, Kurnool and Anantapur, and moved through Belgaum into Dharwar and Kanara. Many swarms came back to the Ghât region after they had moved out into the hot dry Deccan, leaving Bijapur, Sholapur, Belgaum and Ahmednagar clear; these settled in the Ghâts and remained there. At the close of this period, the locusts were within the Ghâts, and spread over an area embracing part of Gujarat, the Western part of Central India and of the Central Provinces, Berar, part of Hyderabad and of Madras; large districts in this area were free from swarms, the locusts only occupying part of the enormous area invaded. On the 24th June, 1904, the Director of Agriculture, Bombay, states (G. R. 5587) that Ahmednagar, Sholapur, Bijapur, Dharwar, Belgaum, Kanara and Kolhapur were practically free from locusts.

The available information as to the whereabouts and movements of locusts is inadequate to detail accurately their history; many places were probably infested with locusts which bred there year after year, and the matter is not known or reported as it excites no interest.

Fifth Period.—Scattering.

After this outward movement, the locust swarms broke up shortly before the end of May. Swarms were no longer to be

seen, and the infested areas contained enormous quantities of active locusts spread and scattered singly. A vast area of country was infested (Plate II.), but little or no damage was done and the locusts had apparently lost the swarming and migrating instinct. This may have been due to lack of food for such vast swarms at that season or to the instinct which leads them to scatter before the period of reproduction. Food was scarce, and scattered individuals spread over a large area would evidently find food where a moving swarm would not do so. In fact, the insect now ceased to be a locust and became a grasshopper, not more numerous than other grasshoppers and no more destructive had there been crops to destroy.

Sixth Period.—Reproduction.

Early in June the rains fell in parts of Western India, and the locusts entered upon the last period. Coupling and egg-laying took place during June and July, depending upon the date on which heavy rain fell. The locusts remained scattered, not swarming or moving, and simply reproduced where they were and died.

By August, and even earlier in some places, practically all the locusts were dead. For a whole year they had lived, spending at least ten months of that time *in the winged condition.*

The periods noted above were roughly as follows :—

Winged locusts	emerged and entered crops.	October 1-20.
,,	,, migrated.	Oct. 20—Nov. 30.
,,	,, remained in forests.	Dec. 1—March 20.
,,	,, migrated.	Mar. 20—May. 20
,,	,, scattered.	May 20—June 10.
,,	,, reproduced and died.	June 10—Aug. 10.

These dates are approximately accurate for the whole mass, although small variations occurred in many places. They represent the average periods for the whole area involved.

PART II.

LIFE HISTORY.

Development of the Reproductive System.

On first appearing in September and October 1903, the locusts were examined to see whether the reproductive system was developed. It was of extreme importance to know when the eggs would be laid and on the analogy of the North-West locusts this was expected at once. The reproductive organs were then found to be very small, consisting of the narrow white ovary or testis in a completely undeveloped condition, with delicate oviducts or vasa deferentia leading to the external genital opening. The body was practically destitute of fat body and the abdomen was largely filled with the air sacs attached to the main longitudinal tracheal trunks. The nervous system, the alimentary canal, the tracheal system present no structures calling for special notice. From time to time, the reproductive system of freshly caught locusts was investigated ; no signs of development were noticed until the following April when it was found that the reproductive organs had increased slightly in size, and were encased in a small mass of yellow fat body.

During May, the reproductive system increased in size ; the egg tubes were distinctly visible, the oviducts growing larger with thickened walls ; the testes and vesiculæ seminales also increased in size and in both sexes a larger amount of fat body was formed. At the same time the locusts became increasingly sluggish ; by the end of the last migration outwards from the forests the reproductive system commenced to occupy a large part of the abdomen and with its increasing growth the flight of the locust became more and more unwieldly and slow.

During the end of May and first week of June the reproductive system became fully developed ; by the 10th of June many specimens had mature reproductive organs and copulation took place. In some places this was delayed until July, and even with locusts caught in any one place there was great variation in the degree of maturity of the ova and testes.

The mature female reproductive system consists of two large ovaries, each formed of about fifty short egg tubes opening into the expanded oviduct, which unite from each side in a single duct passing to the external genital opening: a very small sebific gland opens by a duct above the external genital orifice. (Plate III., fig. 1.) The oviduct of each side becomes a solid twisted cord at the anterior end of the ovary and passes into the anterior portion of the abdomen. The egg tubes form a large yellow mass, cased in a fat body and enclosed in a single membrane embracing both ovaries. The number of egg tubes on each side is 50 to 60, the delicate ends of the tubes turned inwards; the oviducts are laterally placed and somewhat swollen, of a bright orange colour. The posterior end of the body consists of two paired chitinous processes, one dorsal, one ventral, closely pressed together ; the anal opening covered by the pygidium is dorsal, the genital opening concealed by the sternum of the last segment is ventral. (Plate III., figs. 2, 3, 4.)

The male reproductive system consists of two large testes, enclosed in a common envelope, with masses of yellow fat body surrounding them. (Plate III., figs. 8 and 9.) Each testis consists of numerous short fine tubes, opening into the vasa deferentia ; the two ducts unite and open at the hind end of the body ; the accessory glands and vesiculæ seminales have the form of long twisted tubes forming a convoluted mass at the extremity of the abdomen, and open into the vasa deferentia close to the external opening.

The vasa deferentia lead to the penis, a muscular and chitinous organ opening on the dorsal side of the large ventral process ; the penis is retractile and in copulation projects upwards from the ventral process. The spermatozoa are long

needle shaped bodies with minute heads ; they lie in bundles in the vesiculæ seminales at the time of copulation.

Coupling.

With the first rains in June, the reproductive system matured, and coupling commenced within a few days of the rain falling in appreciable quantity and continued during about two weeks.

The male grasps the female with his forelegs on her prothorax, the middle legs on the junction of abdomen and thorax, the hind legs being drawn up ; the body is over the body of the female, the abdomen curling round to one side, so that the penis can be extruded in an upward direction and enter the genital opening of the female. The conspicuous shield of the male genital opening extends in a posterior direction, looking downwards, and the female retracts her abdomen telescopically to admit of the entrance of the penis. The operation is characteristic and cannot be mistaken. The male stridulates, raising the hind leg, running the teeth along the wing, producing a low sharp chirp ; at no other time is stridulation observed.

Coupling lasts many hours and is not complete under fifteen to twenty hours ; a pair coupling in the evening will remain so till the next day. Coupling goes on from day to day, promiscuously ; one may see quite one-third of the locusts coupling daily for at least five days on end and the operation would appear to require more than one day for completion. Many females couple when the ova are immature, others apparently in the interval between impregnation and egg-laying.

Couples separate if disturbed, after making unwieldly jumps along the ground. Coupling locusts may be found on the bushes in wet weather, on the ground in fine. After coupling the male locusts die ; the females remain active, waiting about five days before laying eggs. The transfer of these spermatozoa to the oviduct of the female is a lengthy process. There appears to be no distinct expulsory effort on the part of the male, nor does the structure of the vesiculæ seminales show that such efforts are possible. An examination of the organs

and close observation of coupling locusts suggest that, union being established, the spermatozoa move from the vesiculæ seminales, through the penis, up the oviducts, by their own efforts. It is probable that there is some chemotactic attraction in the ovary, drawing the spermatozoa from the vesiculæ seminales to the ova ; the mucilaginous matter of the accessory glands appears to fill the penis and provide a medium for the passage of the spermatozoa into the oviduct, which is also filled with mucilaginous matter.

Egg Laying.

The deposition of eggs in the ground has been observed in the field and in cages. A female about to lay eggs walks about feeling the soil with the palps, apparently testing its consistency with the jaws. Having found a suitable place, she raises herself on her legs and curls the abdomen over, till the tip rests on the soil. The hooks are then pressed in and the two pairs of powerful digging processes press the earth apart, to the front and rear of the vertical end of the abdomen. This digging continues in a nearly vertical direction, the abdomen steadily descending and the locust moving backwards to get pressure on the hooks. The abdomen is forced in till the hole is about two inches in depth, when the locust is standing nearly over the hole, the abdomen buried up to the basal segment. If the digging has been satisfactory, eggs are laid, the eggs pouring out between the processes, gradually filling up the hole. (Plate IV., fig. 1.) When all the eggs, numbering 100 to 120, are laid, a mass of gum is poured in which covers the eggs and sets as a smooth surface, a little way below the level of the soil. This gum is a frothy white matter, turning slightly buff in colour, which binds the eggs together and covers them over. It is at first soft and frothy, but sets hard in a few hours and the whole egg mass can then be removed intact. The upper part of an egg mass consists of pure gum, containing no eggs. This process takes from one to two hours from the time the locust commences to dig into the ground. A considerable time is required to make a satisfactory hole, after which the

eggs are laid in half an hour. In the field locusts make many ineffectual attempts to lay eggs, digging holes to a certain depth and then finding stones or water or some unsuitable condition. Many of these holes can be found in the field. Frequently the hole is not vertical but curved; it is rarely straight, usually slightly curved, often very much bent, in order to pass some obstructing stone. In soft earth in captivity the eggs may be laid deeper and the white mass of gum is not visible from above.

It is not easy to recognise a laying female except by the fact that she does not move on being approached. On coming close, the abdomen can be seen passing into the soil. Should the hole not be complete, the female will often leap away if disturbed. If eggs are being laid, she moves only with great reluctance and can be carefully observed during the process.

The Egg Mass.

The whole egg mass is from 1 to 2 inches long, nearly cylindrical, straight or curved according to the nature of the ground and the hole. (Plate IV., fig. 2.) When the soil is gravelly, the holes and the egg masses are twisted or curved; in fine soil the egg mass is straight. The yellow eggs can be seen in the gum. Each egg is like a yellow rice grain, cylindrical, about $\frac{1}{8}$ inch long. The egg mass contains about 110 to 120 eggs.

After the gum hardens, the whole egg mass is easily moved intact with a little care. During the course of the development of the eggs, the frothy gum no longer binds the eggs together: this is due partly to the swelling of the developing eggs, partly to the gradual drying of the gum or to other changes in it. The majority of eggs found during the second half of development are loose and not in a compact mass. The eggs change colour during development; the outer skin of the egg is at first transparent and allows the orange colour of the egg to be seen. Later it becomes opaque, a dirty brown colour, getting a tinge of green as the egg becomes mature. Soon after the eggs are laid the female locusts die They lay eggs once only,

in a single mass. In cages they die the same day ; in the field they were found dead in large numbers when the egg-laying was at its height. They apparently do not live long after egg-laying, for it is rare to find living females that have laid eggs.

The periods occupied in coupling, egg-laying and dying were carefully observed in several places, and these agree fairly well. The dates at Shahpur, Thana district, were :—

Rain.	11th June.
First coupling.	15th ,,
First eggs.	20th ,,
Main coupling.	20th to 30th June.
,, eggs.	25th June to 5th July.
Diminishing coupling.	1st July to 8th ,,
,, eggs.	5th ,, to 15th ,,
Locusts died.	24th June to 18th ,,

Similar periods were observed in Igatpuri and Kasara, and these agree with the reports and observations from other places. It may be noted that these apply only to places where sufficient rain fell during the whole period to admit of egg-laying going on continuously.

Eggs Hatching.

After the lapse of the incubation period, the whole egg mass hatches, all the little insects emerging often within a few minutes. The outer eggshell breaks in various ways, the end over the head often coming off as a cap on the head of the young locust, or the shell splitting along its length where the legs press against it. No special device appears to exist for opening the egg ; the young locust apparently presses with its hind legs, either forcing off the end with its head or splitting the egg shell where the spiny tibia presses against it. The young locust may shed the delicate inner skin (Oolemn) inside or come out clothed in it, when it is at once shed. The period within which the eggs hatch varies in different circumstances. The details are discussed in a later section and the actual periods of all eggs hatched in captivity are there given. As a whole, the eggs in the lower lying localities, such as Thana district, hatched in about six weeks ; those at the top of the

Ghâts, where the temperature is lower, hatched in from seven to eight weeks. The conditions at the edge of the Ghâts are peculiar, the heavy rainfall and high winds producing a lower temperature. For most parts of Western India the average period is apparently about six weeks. This agrees generally with observations in the field, where no precise periods can be ascertained owing to the long period over which egg-laying is spread.

Development.

On hatching the young locusts are at once active and commence to feed. The insect is now very small, with fully developed limbs and internal organs, with the sole exception of the wings and genital organs. If food is abundant and the conditions suitable, there will ensue a steady growth in size, entailing frequent moults of the outer hard skin, a development of the internal genital organs and a development of the wings. As the insect feeds, more tissue is formed within its body and at regular intervals the whole skin is cast; the insect then has an elastic soft skin that expands and gives room for a further growth. It is soft only for a few hours and then hardens. When this expansion is utilised another moult takes place. After the third moult the wings appear as tiny lobes, which grow larger at every subsequent moult. At the last moult, the outer skin is fully developed, the insect has attained its full size and can fly. It is still not mature, the full development of the genital organs being deferred until the lapse of many months. The process of development then is a steady process marked by no violent changes. Colour changes occur with every moult and, subsequently, colour changes take place without moults. From the time the egg hatches till the locust dies eleven months later, the development is marked only by (1) the full growth of the wings, allowing of flight and migration, (2) colour changes, of which three are conspicuously marked, (3) the final sudden development of the genital organs after the last migration. The moults in the first period occur with fair regularity. At each moult there is a small change in

colour and a growth in size. In captivity there was a variable number of moults. The following table gives the periods from egg to full grown insect :—

No.	Date of Hatching.	1st Moult.	2nd. Moult.	3rd. Moult.	4th. Moult.	5th. Moult.	6th. Moult.	7th. Moult.	8th. Moult.	Total number of days.
32.	26. VII.	6. VIII.	17. VIII.	9. IX.	9. IX.	16. IX.	26. IX.	5. X.		71.
34.	26. ,,	6. ,,	22. ,,	29. VIII.	7. ,,	11. ,,	19. ,,	27. IX.		63.
39.	26. ,,	6. ,,	18. ,,	29. ,,	5. ,,	16. ,,	28. ,,			64.
43.	28. ,,	6. ,,	16. ,,	25. ,,	4. ,,	11. ,,	19. ,,	27. ,,		61.
44.	28. ,,	5. ,,	12. ,,	20. ,,	29. VIII.	7. ,,	15. ,,	4. X.		68.
46.	28. ,,	6. ,,	15. ,,	24. ,,	1. IX.	8. ,,	17. ,,	5. ,,		69.
49.	28. ,,	5. ,,	15. ,,	24. ,,	2. ,,	10. ,,	20. ,,	6. IX.		70.
50.	28. ,,	5. ,,	12. ,,	19. ,,	27. VIII.	5. ,,	13. ,,	28. ,,		62.
55.	28. ,,	5. ,,	13. ,,	21. ,,	29. ,,	5. ,,	13. ,,	30. ,,		64.
56.	28. ,,	5. ,,	14. ,,	23. ,,	31. ,,	8. ,,	18. ,,	2. X.		66.
60.	25. ,,	1. ,,	9. ,,	17. ,,	26. ,,	2. ,,	9. ,,	19, IX.	3. X.	70.

At the last moult the insect appears in its final shape with fully-developed external genital organs, and it is then able to fly. The two notable points in its history are, first, the colour changes, and, next, the development of the mature reproductive system.

Description of Hoppers after each Moult.

First Stage. (Plate IV., fig. 3.)

Length from head to tail, 7 m.m. (5m.m.).

,, ,, ,, to end of legs. 11 m.m.

General colour green. Eyes dark.

Head grass green, with short yellow-green antennæ ; thorax and abdomen yellow.

Legs and lower part of thorax green.

Legs, antennæ and body speckled with tiny black spots visible only under a glass.

Hind legs with tiny black tipped spines, and short white hairs visible under a glass.

Second Stage. (Plate IV., fig. 4.)

Length from head to tail, 11 mm. (8 mm.).

General colour, green. Eyes dark.

Head green; antennæ slightly brown; thorax, abdomen, and legs green.

The black speckles are abundant on the head, legs and upper part of the body; a dark line on each side of the mid-dorsal line runs along thorax and abdomen, with a light line between.

Third Stage. (Plate IV., fig. 5.)

Length, 13 mm. (12 mm.).

General colour green. Eyes dark.

Head green; antennæ dark brown; 16 joints.

Thorax, abdomen and legs green. Black speckles abundant on the head, legs and upper part of the body.

A mid-dorsal longitudinal white line, with a broader dark line on each side. Mandibles brown tipped.

Pronotum prominent. Meso and Metanotum distinct, the posterior angle slightly produced. Eyes green, with a dark stripe in front.

Fourth Stage. (Plate IV., fig. 6.)

Length, 15 mm.

General colour green, black striped.

Head green; antennæ black; 21 joints, white ringed.

Thorax, abdomen, head, legs, green black speckled.

A dark streak under each eye. Eyes banded in chestnut. Prothorax large, black speckled.

Meso and Meta-thorax small; rudiments of wings green, larger. Abdomen green, much speckled with black.

Fifth Stage. (Plate IV., fig. 7.)

Length, 23 mm.

General colour green with slightly yellowish tinge above: median dorsal longitudinal black stripe distinct; dark speckled all over.

Head green; antennæ black with the white rings fainter; number of joints 22.

Eyes dark brown with a distinct vertical dark streak under each; the streak is white-edged anteriorly and posteriorly.

Prothorax large, green, black speckled with a whitish median longitudinal rudiment of a crest or carina.

Meso-and Meta-thorax green with anterior portion of the dark streak; rudiments of both the wings visible.

Abdomen green, with a distinct black stripe above. The latter is bordered on the right and left by a narrow patch of white colour. A white line on each lateral side; ventral side pea green.

Limbs, green, black speckled especially the hind femora; near the knee joint of the latter there are two (one faint) patches of dark colour which appear like transverse rings.

Sixth Stage. (Plate V., fig. 1.)

Length, 30 m.m.

General colour light green, with the dorsal black line distinct. Body black speckled all over.

Head light green, two rows of dark tubercles extending from the epicranium to the labrum. Eyes with the dark vertical line under each with the white edge well marked.

Clypeus and labrum slightly brownish in colour. Antennæ black, white ringed, joints 23.

Pronotum, large, green, with the dark speckles turned a little brown. A row of dark spots on the hinder edge, 8 or 9 on each side of the median line. The rudiment of whitish crest stated in the last stage has become distinct.

Meso- and meta-notum completely covered above by the rudiments which are 5 m.m. long. The wing nervures are distinctly seen. Two black spots on each wing.

Abdomen, yellowish green, the black patch above with its yellow borders distinct. It extends from behind the wings to the last segments. Black speckled all over. Ventral surface green.

Limbs, green, dark speckled especially the hind legs. The femoral and tibial regions of the latter are brownish in colour. The spines on the tibiæ distinct.

Seventh Stage. (Plate V., fig. 2).

General colour light green, with a brownish tinge all over, dark speckled.

Limbs reddish brown.

Head brownish green, eyes brown, the two rows of tubercles in the clypeal region appear as a pair of parallel ridges dark brown in colour.

Pronotum brownish green; the speckles dark brown instead of black.

The median whitish crest distinct; a whitish rim on all sides of the shield.

Meso-and Meta-notum hidden by wings; wings extend 14 mm. from the pronotum.

The upper edges of the wings touching the median dorsal side of the body are dark. Two dark spots on each wing cover.

Abdomen light green with minute dark spots, and the black dorsal stripe.

Limbs brownish green; the hind limbs have the femoral and the tibial regions brown; the spines appear whitish; a dark streak on the hind femora.

Colour Changes.

These fall into three chief colour schemes, the first or "dry grass colour," the second or "swarming colour," and the third or "wet ground colour."

When the locust becomes winged, it is of a general brown colour, with conspicuous yellowish stripes on the neck and wings. This colour is similar to that found in many grasshoppers which live in dry grass, a colour in which the brown background and lighter stripes assimilate them to the light and shade observed in ripe dry grass. It is conspicuous on green grass or green plants, and very noticeable when in flight. During the first migrating period, the body and head become suffused with brilliant red, bringing a resemblance to the "migratory locust," when it is purple red in colour. This colour is of various degrees of intensity and, though assumed by nearly all, is not absolutely universal. This colour persists through the first migrating

period, the cold weather period when the locust moves in swarms, and the second migrating period. It lasts in fact over the whole period in which the locust forms swarms. One may conjecture that the red colour facilitates swarming ; the main body of a swarm settling on the trees at dusk is brilliant red, easily seen for miles, which may be an important factor in preserving the swarms intact or in gathering the locusts into swarms. In some districts of the Deccan, this colour gave place to a bleached whitish appearance, a faded replica of the first colouring, but this was uncommon. The degree of redness varied greatly, some swarms at Mahableshwar being far redder than some seen elsewhere.

Finally, when the coupling season came on, the red colour gave place to a general darker colour, with streaks of yellow. The ground colour in some was almost black, in others a deep brown ; there was a great variety in colour, but the general effect was to make the locust invisible on the ground. Locusts sitting on the ground within a yard's distance may escape notice till they move. This colouring apparently assimilates the insect to the wet ground so that it may couple and lay eggs undisturbed. There is no evidence that it was not "sexual colouring", but being common to both sexes and giving them an extraordinary resemblance to their surroundings, the rational explanation is that it is a protective colouration.

Such colour changes are not unusual in long-lived migrating locusts. The familiar grasshoppers of India do not change colour in this extraordinary manner, after they have once assumed the perfect form, and it may be assigned to the long life and extensive migrations of the locust.

PART III.

THE HABITS OF LOCUSTS, WITH METHODS OF DESTRUCTION.

It is convenient to recapitulate the periods of the locusts' life and discuss the methods which can be adopted for their destruction, based on their habits and conditions of life.

Flying Locusts.

The flying locust emerges from the grass lands in September and enters the crops. In ordinary years the locust then for the first time is observed, and as it immediately destroys the crops, any method of dealing with it is of great importance.

The daily habits of the locust at this time are as follows :— During the night it ordinarily remains motionless on the plants or on trees, not feeding and apparently numbed with cold. Should the nights be warm, it is active throughout the night and if disturbed drops to the ground and hops away. During October and early November it flies during the night, migrating from place to place. As the sun rises the locust becomes active and commences to feed ; about eight o'clock, it is sufficiently active to fly and may be driven along the crops, flying low and soon settling. At midday, it is flying aimlessly about in the air, feeding on the crops, and when disturbed circling overhead. About 5 P.M. it again settles down, and may be driven in any direction if the breeze is not strong. After that it settles down for the night. The practice of cultivators is to go into the fields and beat tins to frighten the locusts ; as a rule this has no effect except in disturbing the locusts and making them fly aimlessly from plant to plant. During October

1903, it was found possible to clear entirely a field of locusts by beating it through with a line of men ; the work must be done between 7-30 to 9-30 A.M. and 4-30 to 6-30 P.M. At no other time can the locusts be driven. This was effected with great ease; the locusts could be driven out into waste lands or on to babul trees, and in most cases the locusts flew away the next night and were not seen in that village again. This is the only possible method of dealing with them at this time. Attempts were made to drive the locusts into patches of crops which were poisoned. The locusts were driven into such patches but the poison used was too strong and the locust flew away without feeding.

In November, when the nights become cold, the locusts are torpid and helpless at night and may then be destroyed. If they are in the crops, they may be driven out into any adjoining trees or waste lands. They prefer to sleep on trees in the cold nights, clustering on the top of the trees where the sun will strike them when it rises. From November to March, the method of killing the locusts at night when they are torpid is the only effectual one. The locusts then are active by day, usually migrating over the forests a distance of five to seven miles and settling about 5 P.M. in a compact mass on the trees. The simplest way to kill them is to form gangs of labourers armed with brooms, each under one leader, with a number of tree climbers attached to each gang. From 2 A.M. to 6 A.M. the gangs work, the climbers shaking the branches of the trees, the gangs below steadily beating the locusts to death as they fall down. The gangs work from different points and continue till daylight ; those locusts that are not killed by the brooms, gather on tree trunks, on bushes, in ditches and may be swept into bags as soon as they can be seen. The whole area treated is then swept up, the locusts piled in heaps and either burnt, treated with a solution of disinfectant, or buried. Many variations of this treatment were tried and none were so effectual as that described above. It is advisable to mark down at evening the exact spots where the locusts settle, as it is not easy to find the

best place to work at in the darkness. The same method is practicable in every village and when sufficient inducements offer, the villagers practise it successfully. From November to March, this method alone proves satisfactory, for it is impossible to destroy the locusts by day, as they are active and move readily. The same is true during the next two periods, the second migration and the scattering period. When the locusts are torpid at night they may be destroyed ; but when they are scattered over the country and no longer in swarms, they cannot be attacked on any large scale.

With the first fall of rain, the coupling period commences, and the locusts can then be caught by hand during the day, for they are sluggish and move little. In wet weather they sit on the bushes and may be caught in the hand. When actually coupling, children catch them easily and it is simply a question of offering a sufficient reward for a given quantity of locusts. Though they are then scattered, there are particular spots where they congregate in greater numbers, and where they may be caught fairly readily. This brings the flying locusts to an end, the eggs and hoppers alone remaining to be destroyed.

During the egg laying season it was expected that it would be possible to see locusts laying eggs in large quantities in special places, and that these locusts could be destroyed. This was found to be incorrect and there is little to be gained by trying to find locusts in the act of laying eggs. An egg-laying female can be approached and will not move if she has once commenced the actual deposition of eggs. As a rule about one to one and a half hour is required for the female to dig the hole for the eggs, and during this time she will immediately fly away if disturbed. After that, the actual laying of the eggs commences, and the locust will not move even if the soil is dug into beside her and the eggs laid bare. There is practically only a period of half an hour during which the locust can be found actually laying eggs.

During the course of continuous observation of locusts at Igatpuri, a considerable number of locusts were actually seen laying eggs, but this required a very great amount of

observation. At the best, not more than ten or twelve locusts would be thus seen in the course of a day.

Finding Eggs.

It is no easy matter to find any quantity of locust eggs except in specially favourable places. Continuous observation of coupling locusts showed that eggs were laid near the places where they coupled. There are no regular coupling grounds, and the utmost that can be said is that there are some spots which the locusts prefer both for coupling and egg-laying, and that in any village, when the locusts are most numerous, the eggs are likely to be found. It is useless to look for locusts laying eggs. Far more eggs are found by looking in the ground in what are likely to be the best places. The holes made by the locusts are characteristic, but are soon obliterated by rain. It is practically useless to look for any holes, so many beetles, crickets, etc., making holes of similar size. When locust eggs are laid and no rain falls, the hole, with its smooth even layer of light-coloured gum inside, can be seen readily ; in most cases rain falls and obliterates all external signs of eggs. The most satisfactory method is to scratch the ground with a strong knife or any small digging tool in those places most likely to contain eggs. In Igatpuri, with abundant locusts laying eggs, a fair number of clusters were found, but to find one hundred per day would have required ten to twelve hours continuous work in the best places. In other spots, larger numbers of eggs were found in exceptionally good places. On the whole, an experienced man with a good eye for locust eggs and an understanding of the best places to look for them would be lucky to find as many as one hundred egg clusters per day. (See also page 62.)

Where Eggs are laid.

It is found that locusts prefer certain spots for egg-laying and that the choice of these spots depends chiefly upon the quality of soil, the relative degree of wetness, the character of the vegetation on that soil and surrounding it

In the first place, dry soil is unsuitable and locusts in captivity absolutely refuse to lay eggs in dry soil. In a cage containing some wet and some dry soil, the eggs were all laid in the wet half; locusts kept in a cage with dry soil die before laying eggs in the ground, the eggs being involuntarily laid on the sides of the cage a short time before death. This phenomenon is common with many insects which lay a large mass of eggs in one place, the physiological need of laying eggs overcoming the restraining force when the insects grow weak before death. Secondly, locusts will not lay eggs in waterlogged soil. Eggs were never found in places where water could stand, even if the other conditions appeared favourable. Nor would locusts in cages lay in absolutely waterlogged soil. Apparently a soil that is well soaked and drained is the first requirement. Thirdly, locusts rarely lay where there is much bushy vegetation shading the ground. In the lower slopes of the hills where a bushy jungle predominates, eggs are laid on the fringe of open spaces, or in the open spaces. Fourthly, eggs are laid freely in captivity in soil made up by hand and smoothed by watering. When the soil was again disturbed and not watered or rained on, no eggs were laid; locusts apparently prefer an untouched smooth surface. Fifthly, locusts prefer the softer, less tenacious black soil to the stiff reddish clay soil, where both are well soaked with rain. This is probably simply a question of the ease of digging and of the danger in the clay land of the hole becoming waterlogged. The following lands contain the bulk of the eggs:—

(1). Rab lands, *i.e.*, land in which rab materials had previously been burnt, on which nagli (*Eleusine coracana*) or other seedlings were growing. Large numbers of eggs were found in rab lands and the locusts congregated in these rab fields among the seedlings. The soil here is loose and well drained, and the nagli affords food to the locusts. In the ploughed fields round these rab patches locust eggs were practically absent, unless the land had been sown or planted.

(2). Embankments of low-lying fields. In Igatpuri, eggs were found in the bunds of the rice fields though never in the

fields themselves. The top or the side of a bund offers a suitable place and a considerable number of eggs were found there.

(3). Grass land. Open land on hill sides, or grass land on the flat seems to be the favourite place for eggs. The grass strips between fields also contained eggs. In hilly country, the locusts remained on the lower slopes just above the valleys and eggs were extensively laid there. The grassy land with bush scrub was especially selected, possibly because the bushes afford food and cover from rain.

(4). Cotton and other fields. In the flat country of Rajpipla and Amraoti, eggs were found in the fields, usually near the edges close to a grass strip. On the whole, fewer were laid in such places. Fields recently cultivated contained no eggs, and only in fields where the surface was beaten flat with rain and a crop coming up were eggs found in any number.

On the whole it may be concluded that little is to be expected from looking for eggs or from offering rewards for eggs ; in exceptional places eggs will be found in some number, but where a large area is infested, practically nothing can be done with the eggs. In a later section, the effect of ploughing, etc., on eggs is discussed. It is interesting to note that locusts do not lay eggs freely in forest land but in open grass lands. Though the locust swarms live in forests, they appear to break up and seek the open grass lands before the coupling period commences. Thus it is that, when the swarms have broken up, locusts are found more readily in waste and grass lands bordering on forests than in the forests themselves. Waste lands in Belgaum and Dharwar probably contain the locusts that come out of the forests of the Ghâts in those districts and in Goa. An essential part of the locusts' movements would thus be the move out of the forest to lay eggs, with the corresponding move back to the forest when the new locusts become winged.

Hoppers.

Within five to six weeks of the eggs being laid the hoppers hatch. These live in the grass lands and feed upon grass and

other vegetation. Their life occupies some six weeks, during which time they are unable to fly and can only leap. They are active almost from the moment they hatch and commence feeding within an hour.

In this stage the locust can be destroyed only if very abundant. The hoppers do not pack into swarms and move over the country. They are stationary, finding abundant food where they hatch and remaining there so long as food is available. They are widely spread and practically infest the whole of the country in which they hatch. There is no way of gathering them together, and the method to be used must be one capable of being applied in every village over a vast area.

The experience of the 1883 campaign resulted in the discovery that bags were the simplest means of destroying hoppers. Further methods tried in 1904 were the American Hopperdozer, the Russian method, and the use of poisons. The Hopperdozer was abandoned on trial as offering no advantages over the bag in a country where manual labour and simple appliances are alone available. The Russian method, which consists in a revolving axle set with twigs, which brushes the hoppers into a bag, was found to be perfectly feasible, and would be eminently useful over large stretches of open country. For the cultivator a simple system is necessary and as the result of a series of experiments, the bag and frame described below was devised.

The frame used has an opening four feet wide, two feet high. The bag has the same opening, and is five to seven feet deep. When the frame can be drawn over the ground, it is so used. When bushes or other obstacles intervene, the bag is taken off, a bamboo placed in each side to hold it open, and two men drag the bag. (Plate VI., fig. 1.) For large stretches of open country, a longer bag is used with an opening 12 feet by 2 feet, and a depth of 8 feet. A useful pattern of bag was held open by four bamboos, the horizontal ones forming handles; the mouth of this bag closes automatically if the bamboos are not lashed but fastened by a

bolt passing through the two bamboos. (Plate VI., fig. 2). The following leaflet was published in English, Gujarati, Marathi and Hindi describing this appliance :—

Methods for Destruction of Hoppers.

Experiments made in destroying hoppers have shown the following method to be simple and efficacious. A bamboo frame is prepared as in the directions given below ; to this is attached the bag also described below, which has an opening four feet by two feet, which is kept open by the frame. Cords are attached to the frame and it is drawn rapidly over the ground. Hoppers get into the bag and periodically the bag is taken off, twisted up and the hoppers inside crushed.

The frame and bag is so light that one man can easily draw it rapidly up and down, sweeping up the hoppers. This method is available in grass land, in young crops, wherever the growth of vegetation is not too high. In cases of crops, bushy land, etc., the bag may be detached from the frame, two bamboos placed at the sides of the mouth and the bag drawn by two men with cords. It can then be drawn through and over crops, grass, bushes, etc., and is extremely easily manipulated.

These two methods of using the bag should be sufficient to destroy hoppers in large quantities in almost all kinds of land. For use in large areas of grass lands or crops, larger bags can be prepared and used without frames, simply with bamboos placed at the sides to keep the mouth open.

The dimensions given are those found handy for one or two men's work. Large bags for open lands may have an opening of twelve feet wide, two feet high, and a depth of eight feet. In this case the bag should be weighted with pockets of sand sewn into the lower edge of the mouth and the corners of the back. Two men can manipulate such a bag and cover a large area of land.

To make a Bag and Frame with opening of four feet by two feet.

Sufficient strips of cloth are taken, each fourteen feet long, sewn together by their long edges to make a piece fourteen

feet by six feet. The two ends are then brought together and the sides sewn up. This makes a flat bag, to which strong cloth tags are sewn, the first at one seam, the next two feet from that, the third four feet from the second, the fourth two feet from the third and four feet from the first. Bamboos of two feet length are fixed between the two pairs of tags two feet apart and the bag is ready. (Plate VI., fig. 1.)

The frame is made of four pieces of bamboo, (*a*) each four feet three inches long, laid in a square, the ends of two bamboos on the ends of the other two. Two cross pieces (*b*) of split bamboos, each five feet eight inches long, are laid diagonally across the square. Two pieces of bamboo, each two feet three inches long (*c*), are placed upright at the corners of one side, and two split bamboos (*d*), each four feet eight inches long, are placed from the top of these uprights to the nearest corner. A cross bar (*e*), four feet three inches long, is then placed to unite the top of the two uprights. (Plate VI., fig. 2.)

As the bamboos are placed in position they are bound with string or fibre in the order given above. Enough bamboo should project at the ends to allow of their being bound together. This makes a frame to the front of which the bag above is attached by the tags.

In these figures, three inches extra length is allowed to permit of the bamboo being bound; the resultant frame is then of the size to accommodate the bag. The two feet long bamboos used for keeping the bag open are inserted only when the bag is used alone; when the bag is attached to the frame, these bamboos are removed and the tags of cloth knotted to the frame, so that the bag can be at once removed and twisted up. In place of bamboo, strips of wood may be used.

Rewards.

The question of the amount to be offered for locusts and locust eggs is one that can be answered only from a consideration of local circumstances. For winged locusts during the cold weather ¼ to ½ an anna per seer (2 lb.) was sufficient to give a

fair wage to an active man. Later when the locusts were coupling and it was important to destroy them, ½ to 4 annas per seer was paid. A seer of locusts contains about 450, or about 400 in the coupling season. A seer of eggs contains about 1,000 eggmasses, from 100,000 to 120,000 eggs. As one egg mass is about one-third the weight of a female locust or one-fifth of the pair of locusts, 5 seers of locusts are required to be equal to one seer of eggs, and every five seers of locusts killed in the coupling season is equivalent to one seer of eggs destroyed. The reward for eggs was accordingly fixed at rupee one per seer. The average weights of the locusts are :—

	Grains.	Per seer.
Male	25-30	640-466
Immature Female	30-35	466-400
Mature	40-45	400-350
Egg-cluster	12-15	1170-1000

Food Plants.

The locust swarms on first emerging fed principally upon *juari* (*Andropogon sorghum*) and *tur* (*Cajanus indicus*), and though cotton was abundant did not touch it even when they were driven into the fields of cotton. Bajri (*Pennisetum typhoideum*) and other millets were eaten, as well as sugarcane to a slight extent. Oilseeds were not seen to be eaten but the Director of Agriculture, Bombay, informs me they eat oilseeds in the Ahmedabad District. Mango and citrus trees were extensively eaten, also the cocoanut and toddy palms. During the early rains of 1904, the seedling *nagli* (*Eleusine coracana*) was much eaten. Large numbers of forest trees and many bushes are eaten, though they prefer certain kinds when they can be obtained. The 'neem' *melia azidarachta* is one tree that is apparently little eaten.

Dead Locusts.

When locusts die, decomposition causes the usual odour in a few hours. This attracts numerous insects, which feed

upon the corpse and destroy it. These insects include ants, Scarabeid beetles, (*Onthophagus spp.*) and Histerid beetles (*Hister spp.*)

The ants carry off the carcase in pieces and feed upon the decomposing interior. The Scarabeids feed upon the decomposing interior and retire into holes in the ground which they make below the corpse. The Hsterids feed also on the interior of the corpse. The result of this is that a dead locust vanishes in a few hours and when the locusts are dying off in large numbers, such is the rapidity with which they vanish that it is correctly said they disappear; careful search during the time locusts were dying, showed that moribund and dead locusts were to be found as would be expected, but they vanished so soon that only careful observation would show that they were dying at all. Fifty locusts put on the ground in the evening vainshed by next morning. Similarly dead locusts thrown out of the cages in the morning disappeared during the day.

Locusts in Cages.

Locusts live well in cages, if looked after carefully and fed well. The best pattern of cage is six feet high, and at least four, preferably six, feet square. The sides may be wire gauze, the top wood. A door should be placed in one side occupying the whole or half of it. Such a cage can be put down anywhere and food grown on the soil for the locusts beforehand. It is advisable to paint the whole cage with arsenic solution or some other compound to preserve the wood-work from white ants and the gauze from excessive rusting. For obtaining locust eggs and keeping them under observation, smaller cages which fold up, can be used. Those used in this investigation were three feet cube, the top of wood, the sides of wood and wire gauze. (Plate XIII.) Each two sides are hinged and fold back, fastening together with hooks when set up. A door one foot wide stretches up the middle of one side. Eggs are laid in such cages either in the ground or in boxes of earth. Green food must be given twice daily. The common squirrels will do

their utmost to break into such cages if they contain locusts, and the wire gauze should be well fastened down, with strips of wood and not simply tacked.

Enemies of Locusts.

The Bombay locust suffers from the attacks of enemies which lessen its numbers and form a natural check upon its increase. It is difficult to estimate the relative importance of these checks or their gross aggregate effect upon the swarms.

The common grey-necked crow feeds upon adult locusts at all times; when the swarms move about in the crops during September and October, the crows congregate in great numbers to feed upon locusts. Moribund locusts that had been treated with insecticides and were comparatively helpless were snapped up eagerly, the crow then not having the trouble of chasing his prey. Egg-laying locusts also were constantly preyed upon, the crows sitting on trees near the *rab* lands, waiting till a locust settled down to lay eggs.

Monkeys are fond of locusts but are probably not numerous enough to make any effect. If the "Monkey test" is of any value, locusts should be good food for man.

The common striped squirrel is also fond of locusts and eats them at every opportunity. This is the chief difficulty encountered in keeping locusts in cages, as squirrels will do their utmost to break or tear the wire gauze.

Two parasites have come to light, one internal, one external. Locusts have been found in Rajpipla, in Ahmednagar district and other places, infested with large maggots, which live in the abdomen and feed upon the tissues. Specimens were forwarded by the Political Agent, Bhopawar Agency, who said—"The disease apparently commences just above and behind the hind leg of the locust and the maggots spread thence throughout the body". Such flies are common parasites on insects ; it is impossible to estimate the value of this insect, as most of the infested locusts would be killed and not be seen. A similar parasite (*Miltogramma duodecim—punctata*) attacks the migratory locust, *A. peregrinum.*

The external parasite is a minute scarlet organism, which clusters on the lower wings. In some districts the cultivators believe these to be the eggs. Specimens were sent to R. I. Pocock, Esq., Zoological gardens, London, who identified them as the young of *Trombidium grandissimum*, the large red velvety mite. This mite has been found laying eggs in large masses in the ground beside the eggs of the locust ; the young are common on many insects and spiders and lead a parasitic life in their larval stage.

Eggs are attacked by at least three distinct organisms. The first is a beetle grub, a yellowy white insect with three pairs of legs found in the centre of egg clusters, feeding upon the eggs. This grub eats the eggs, remaining in the egg cluster till all are devoured, by which time it is nearly one inch in length. Of the many eggs found, a very small percentage are thus attacked. Eggs in damp soil are attacked by a minute white worm, scarcely visible to the naked eye. It is found in great numbers in egg clusters, but only a very few have been found to be attacked. This worm is to be described as a new Enchytraeid worm.

The third is an ichneumon (*Scelis indicus* Ashm.) which lays one egg in each locust egg. Specimens were reared from eggs collected in Igatpuri, only part of the egg cluster being affected, the remainder hatching normally. Specimens from Peint and Sindked (Khandeish), were also sent in by Mr. J. B. Knight, Special Assistant, Department of Agriculture, Bombay.

The common grey-necked crow also feeds upon eggs, digging them out of soft ground with its beak. Suspicion attaches to certain beetles, but no confirmation could be obtained of the fact of their destroying sound eggs.

The Effect of Weather on Locusts.

As the Life History of a locust occupies one year, it thus passes through the various temperatures and alternations of wet and dry weather that occur in Western India. It may be said that weather is normally without effect on eggs ; eggs are laid only after rain has fallen and chiefly in places where wet

weather is continuous from the beginning. Rain is without effect on eggs, as long as they are laid in a place whence the rain drains off and does not stand. Even when exposed without covering to heavy rain at the top of the Western Ghâts, the eggs remain healthy. As eggs are not found in places where water stands, it may be said that rain is without effect on them. Not so dry weather ; during the first three weeks eggs that become even moderately dried, shrink and die. Even in the intensely moist air of the Ghâts, undeveloped eggs kept in the air away from actual rain shrunk up and did not hatch. The same is true of eggs in soil that is allowed to dry. When the development has proceeded, the egg being some three weeks old, dryness is without effect. During the last half of the period, eggs may be kept dry, and yet will hatch readily and freely. Below are given the dates of hatching of eggs treated in various ways. It is noticeable that eggs kept water-logged for some days when first laid, if afterwards allowed to dry, hatched. Also that eggs kept throughout in very moist soil, whether actually water-logged or not failed to hatch. This is possibly due to asphyxiation of the eggs kept in captivity for experiment ; those that hatched best and most speedily were kept moist and allowed to dry in the second half ; the soil was loose and porous and the hoppers had no difficulty in obtaining air.

We may conclude that (1) eggs are unaffected by rain, but do not hatch if kept in water-logged soil throughout ; (2) eggs exposed to rain, without sun, hatch ; (3) undeveloped eggs exposed to the air and not wetted, die ; (4) in the early stages, eggs exposed to sun for one day are killed ; (5) dryness in the second half facilitates the hatching.

The following were the facts elicited from the experiments with eggs in 1904 :—

Eggs laid in earth and exposed to all weathers and kept moist, seventeen clusters hatched and ten died.

Eggs laid in earth and exposed to sun without water, all died.

Eggs laid in earth and kept moist without exposure to sun, fifteen out of sixteen clusters hatched.

Eggs laid in earth and kept under shelter in the damp air of Igatpuri for the first half of their incubation, five out of eleven clusters hatched.

Eggs laid in earth and kept under shelter without water for the whole of their incubation in the dry air of Surat, all died.

Eggs laid in earth and then covered with water for varying periods, two out of five clusters hatched.

The period of incubation of eggs laid in earth and exposed to all weathers, with the addition of water when necessary, was shortest (39 days) at Surat and Shahapur, was longer (42 days) when the eggs were for the first half at Igatpuri and for the latter half at Surat, and was longest (55 days) when kept for longer periods at Igatpuri. This is probably due to differences in temperature. The degree of moisture appears also to have an effect on the period, as eggs kept dry at Surat hatch later than those kept damp under the same conditions at Surat, and this is true also of eggs at Igatpuri.

Locust Egg Clusters.

	Hatched.	Failed.
I. *Laid in captivity in Earth.*		
Kept dry in shade	5	7
Kept dry in sun	.....	3
Kept damp in shade	15	1
Kept damp in all weather	17	10
Waterlogged three days	.....	2
,, one day	1	.....
,, one week	1	.....

II. *Collected.*

Eggs kept dry under shelter in earth failed.

Eggs kept in earth with rain or sun, kept damp, all hatched.

Eggs in a box without soil died, unless the incubation was advanced, whether kept damp or dry. If the eggs were new, they went mouldy if kept damp. If near hatching, the drying facilitates the hatching.

TABLE I.

Eggs laid and kept exposed to sun and rain.

Locality.	Date Laid.	Date Hatched.	Period in days.	
Surat ...	20 VI	25 VII	35	
,, ...	20 VI	31 VII	41	
,, ...	20 VI	1 VIII	42	Average 39 days.
Shahapur ...	27 VI	6 VIII	40	
,, ...	29 VI	1 VIII	35	
Igatpuri I ...	23 VI	15 VIII	53	
,, ...	22 VI	16 VIII	55	
,, ...	22 VI	18 VIII	57	
,, ...	26 VI	17 VIII	52	Average 55 days.
,, ...	26 VI	19 VIII	54	
,, ...	26 VI	24 VIII	59	
Igatpuri and Surat ...	1 VII	2 VIII	32	
,, ...	6 VII	15 VIII	40	
,, ...	6 VII	18 VIII	43	Average 42 days.
,, ...	8 VII	25 VIII	48	
,, ...	13 VII	27 VIII	45	
,, ...	13 VII	29 VIII	49	

TABLE II.

Eggs kept damp under shelter.

Locality.	Laid.	Hatched.	Period in days.	
Surat ...	20 VI	10 VIII	51	
Igatpuri ...	23 VI	10 VIII	48	
,, ...	24 VI	14 VIII	51	
,, ...	26 VI	16 VIII	51	
,, ...	26 VI	18 VIII	53	
,, ...	26 VI	18 VIII	53	
,, ...	26 VI	18 VIII	53	
,, ...	26 VI	18 VIII	53	Average 51·6 days.
,, ...	26 VI	17 VIII	52	
,, ...	26 VI	19 VIII	54	
,, ...	26 VI	20 VIII	55	
,, ...	30 VI	21 VIII	52	
,, ...	30 VI	22 VIII	53	
,, ...	30 VI	22 VIII	53	
,, ...	5 VII	26 VIII	52	

TABLE III.

Eggs laid and kept dry under shelter.

Locality.	Laid.	Hatched.	Period in days.	
Igatpuri ...	26 VI	8 VIII	43	
,, ...	22 VI	28 VIII	67	
,, ...	26 VI	18 VIII	53	Average 55 days.
,, ...	26 VI	20 VIII	55	
,, ...	23 VI	20 VIII	58	

Hoppers.

Neither rain nor sun affects the hoppers. The heaviest rains appear to be without effect on hoppers, nor does sun in any way affect them so long as they have food. It is generally believed that a heavy monsoon kills the hoppers, but no foundation for this belief can be traced.

When rain does not fall in sufficient quantities to produce abundant moist grass crops, the hoppers die. This is readily understood, since hoppers require large quantities of fresh green food, the moisture in the food being their only supply of water. It was also found impossible to rear hoppers unless in a moist atmosphere; where the air is dry, the green food soon dries up and the hoppers then die. So sensitive are they, that it was found impossible to rear hoppers at Surat during the dry weeks of 1904, except in large glass bottles; in cages the hoppers died off rapidly in spite of a liberal provision of green food and damp earth. In 1905, a single hopper was reared without any difficulty in the damp air of Pusa in an open cage.

Locusts.

The *flying locust* emerges during the warm weather at the close of the rains and is unaffected by high temperatures. The steady high temperature of the Western Coast has the effect of keeping the locusts active day and night if necessary.

From October to June, there is little rain and when the heavy rains come, there is no effect save that of the immediate coupling and laying eggs. The heavy rains of the Ghâts are without other effect on them; when a rain-storm comes on they settle on bushes or trees, and are in no apparent degree affected.

The effect of the rain in producing coupling and egg laying is probably a secondary one, in that they then are able to lay eggs in the wet ground, and they live till the rains for that purpose. It cannot directly be assigned to the effect either of rain beating on them and gradually killing them or to any direct physiological effect. The significance of the first fall of

rain is one that must not be lost sight of ; locusts will apparently not couple or lay eggs until rain has fallen. When the rain falls in sufficient quantity to penetrate a few inches into the soil, the locust couples and lays eggs. Should the locusts be in a place where rain is much delayed, they may die or may be able to live for some weeks only until rain comes. Such a contingency seems to have occurred in 1904, and it may be a very important factor in naturally checking the increase of the locust. So long as the locust can remain in the Ghât forests, and find plenty of food, it is likely also to find sufficient rainfall in June. But if pressure of numbers drives them forth into the arid Deccan, and the rain delays at all, the effect may be very great. During 1904, the locusts on the Ghâts were dead by the 20th July. Scarcely one could be found. Yet at that date, many could be seen in the Central Provinces and Behar, and with the later arrival of rain there, coupling, egglaying and dying were all correspondingly delayed. This point is one of great importance in fixing the approximate dates of egglaying and appearance of hoppers. It is stated that locusts are more abundant after a year in which the rains are late than in a year of normal rain, and it is believed that the heavy rains destroy the small hoppers, the latter growing large enough to resist the rains when the monsoon bursts late. This is opposed to the experience of this year ; rain is without effect upon hoppers of all sizes and the explanation may be sought in the better hatching of eggs in a dry year than in a wet one, provided enough rain falls to allow the locusts to lay eggs and to keep these eggs damp in the first three weeks. Thus a light rainfall in June, with occasional showers until August, would appear to give the ideal conditions for locust eggs ; and this means that from the point of view of the crops, the rain only falls in August. The evidence of 1903 certainly shows that a heavy rainfall in July and August is without effect on hoppers ; in South Gujarat rain fell in late May and early June, the locusts subsequently disappearing as they would naturally do after laying eggs. Heavy and continuous rain fell from July 12th onwards, and subsequently immense

swarms of locusts appeared over this area. The explanation most likely is that the light early rainfall facilitated the hatching of eggs, and it may be considered probable that this accounts for the concurrence of late rains and many locusts.

The Effect of Insecticides on Locusts.

Insecticides act in three ways on insects, through the stomach, through the skin or spiracles, and through the respiratory system. With so large and active an insect as the Bombay locust we should use a stomach poison if possible as being the most reliable, and use arsenic as the best stomach poison. Arsenic can be used in two ways, in solution in water or as an insoluble compound.

Both have been tried on locusts in captivity: locusts were fed with (1) fodder dipped in the standard lead arseniate wash, *i.e.*, 1 lb. lead arsenate, 5 lb. jaggery, 100 gals. water. (2) Fodder dipped in sodium arsenate 5 lb., jaggery 40 lb., water 200 gals. (3) Natal locust mixture, on fodder and in a saucer. The first killed eighty per cent in 12 hours, the locusts feeding on the fodder. The second and third killed none, the locusts declining to feed on the fodder or to drink any of the mixture. It may be pointed out that in (1) the mixture is insoluble, probably not tasted by the locusts and the same as used in crops for other insects: in (2) and (3) there is a large proportion of soluble sodium arsenate, that might taste unpleasant and deter the locust from feeding: also the solution is very strong and syrupy. In all cases locusts refused the strong solutions and were killed by the weak solution. The question of using arsenic as a poison for locusts has been tried in many countries, and in Natal considerable success has resulted from the use of arsenical mixtures as poisons. The chief objections to the use of arsenic in India are (1) the danger to cattle if the arsenic is strong enough to poison them, since the mixture, if to be used generally, must be used freely and without careful supervision; (2) the difficulty of obtaining and distributing it over large areas; (3) its application.

The Natal locust mixture contains 1 oz. of caustic soda, 4 oz. of white arsenic, 4 oz. of ground valerian root, and 80 lb. of jaggery or sugar in every five gals. of mixture. It is a thick syrupy solution containing soluble arsenic. It is highly poisonous to cattle. It requires care in its preparation and will kill living plants on which it is placed. Its use would be for painting or dipping forage which would be placed in the fields where the locusts would find it. It failed absolutely with Bombay locusts when applied to juari plants, when put on bundles of grass and juari in the field amidst a swarm of locusts, and when fed to locusts in captivity.

Arsenic as used on crops is used in an insoluble form, in very weak strength in water. It poisons locusts in captivity, and does not poison cattle. A number of experiments were made by Captain Walker, M.R.C.V.S., Punjab. His notes are reprinted and sum up the question of poisoning cattle.

Copy of a report by Captain G. K. Walker, Indian Civil Veterinary Department, on the result of experiments with the arsenical solutions, during the year 1903-04.

I have been able to do some feeding experiments with arsenical solution on cattle. I have not been able to give much time to the work and the experiments are not so complete as I should desire ; still they are useful.

I first tried the solution recommended by the Natal Entomologist (Agricultural Journal of Cape of Good Hope, January 1903). The formula being 1 lb. of arsenic to 10 gallons of water. White arsenic ($As_2 O_3$) from the bazar was used and washing soda and ghoor (instead of treacle) employed in addition. It may be said that as a dissolving agent washing soda seems quite useless, and although the arsenic appeared to be dissolved when the water was raised to boiling point, when the water cooled, very little, if any, appeared to have dissolved.*

This is very objectionable as if used it can be readily seen that an animal might receive a large quantity of undissolved salt with a relatively small quantity of fodder and an unequal distribution of the arsenic cannot tend to success.

Mr. Lefroy seems to think that undissolved arsenic though harmful to locusts will not hurt animals. This is an erroneous idea, arsenic in any form is very poisonous to cattle and being an accumulative poison continued doses harmless in themselves, eventually cause symptoms of poisoning.

* It requires continued boiling to dissolve [H. M.-L.]

To return to my experiments—a bullock was given 12 seers of churry (jowar) on the leaves of which some of the solution was painted with a brush. This animal was vey ill next day with some symptoms of arsenical poisoning, and was found dead on the third morning after. About two pints of solution were used, and it is possible the animal may have received as much as three drams of arsenic, presuming none of the solution was spilt in the application. Ten grains is a full medical dose for cattle, so the result is not to be surprised at. I made a post-mortem and tested the contents of the stomach, in which I found arsenic in considerable quantity.

It is true the animal was a miserable half-starved creature, but this added to the value of the experiment as the conditions were natural.

The same remark applies to the subject of the next experiment.

I next tried the formula given in Indian Museum Notes IV, No. 3, 1899, p. 139, which is a much weaker solution, *viz.*, 1 lb. to 32 gallons. The dissolving agent in this case is caustic soda. I used caustic potash which is easier to get, and the arsenic dissolved easily and did not precipitate on cooling.

The bullock had 32 oz. of solution painted on 16 seers of churry. He left about five seers of this and was very ill next day with symptoms of poisoning, in fact he looked like dying, so I ordered antidotes to be given to save him.

If he had eaten the whole 16 seers he would possibly have received as much as 96 grains of arsenic (as the maximum quantity).

This bullock is still alive (8-12-03), but very ill in spite of antidotal medicine. I fear he will die.

A fowl fed on grain soaked in the solution is still alive and shows no symptoms of poisoning.

Owing to the necessity of leaving headquarters to-morrow the above is as much as I have been able to do.

It is obvious that very serious danger to cattle is to be apprehended if crops to which they have access are sprayed with arsenical solutions.

No doubt, many cattle would feed with impunity, because I fail to see how one can ensure an even distribution of the fluid, and it is certain that much would be wasted. It is unlikely that animals in the ordinary course of events would be allowed to eat a standing crop for a sufficient number of consecutive days, to obtain a poisonous dose, if the solution used was a very weak one, as presumably only stray cattle would be allowed to eat the crops in this way.

When however the crop is cut it would probably, in many cases, be used as "Chop" or Bhoosa, and the arsenic would still be there. I should apprehend chronic arsenical poisoning if the animal were fed for any period from a sprayed crop, and the symptoms would be more of a debilitating disease. Poisoning might not be suspected owing to the gradual course of the disease, but the fact would remain that arsenic caused the mischief.

Chronic arsenical poisoning is met with in the neighbourhood of the tin and smelting furnaces of Cornwall and Wales.

Animals vary tremendously in their susceptibility to arsenic, large doses have little effect sometimes, and small doses will often act with great violence especially if given for many consecutive days, owing to the accumulative nature of the poison. The death of a horse is recorded from arsenical poisoning from a dose of five grains daily for eight days; 30 grains a day killed a horse in four days. According to Mr. Lefroy's estimate of 20 grains a maund, it would be possible for a bullock to receive about 10 grains a day. This if continued long enough would certainly cause symptoms of poisoning.

I am inclined to think that spraying crops with arsenical solutions especially if left in the hands of irresponsible men would be very dangerous to cattle. I am disposed to recommend a trial of the system advocated on page 85 of Agricultural Journal of Cape of Good Hope, January 1903, in which horse dung and arsenic is the bait.

This would have to be put down in fenced off places or raised off the ground and buried when done with. Animals (cattle) though not partial to horse dung might pick it up especially if flavoured with sugar; and would have to be prevented from gaining access to the bait.

Copy of a Note from Captain G. K. Walker, Superintendent, Civil Veterinary Department, Provincial Circle, to W. C. Renouf, Esquire, Director of Land Records and Agriculture, Punjab.

I have made a further experiment on a bullock as you required with the arsenical solution recommended by Mr. Lefroy, *i.e.*, a solution of lead arseniate paste (1 lb.-100 gallons of water, plus 10 lb. of jaggery).

The arsenical paste is soluble in hot water, but a sediment is thrown out when the water becomes cold. Careful stirring is therefore necessary before using the solution.

From the 24th January to the 1st February the bullock received 8 seers of green oats in the morning and 8 seers of green oats in the evening.

The morning feed was painted with the solution, about 12 oz. being used, but the evening feed was given fresh. From 2nd February onwards both feeds were painted, and the amount of solution used 24 oz. a day.

The experiment was discontinued on 23rd February, the animal being in perfect health.

In 30 days therefore the bullock might have received about 5 drams of lead arseniate presuming none of the solution was lost in the application.

I might say that in face of the above experiment and taking into consideration the strength of the solution, I consider it very unlikely that any harm is likely to come to cattle that may happen to feed moderately on crops sprayed with Mr. Lefroy's solution.

If arsenic can be used to poison locusts, it would seem better to use the weak solution of lead arseniate, which will have no ill effects when once applied to plants. I do not anticipate any value in its use against the Bombay locust. For hoppers, it would have to be applied in large areas of grass land, and would wash off with rain. The hoppers do not pack into swarms and eat down a field; were this the case it could be used and would kill many. For flying locusts if it could be applied to juari fields for instance, the locusts would be poisoned if they stayed there. When the locusts first emerge, the fields they come into could be poisoned. Lead arseniate can be applied safely only in water. It can be applied in powder, but only extremely careful application could guarantee that cattle would not be poisoned. Facilities for applying washes on crops are practically non-existent in India, and the cost of introducing them in sufficient number would be prohibitive. Later in the season, the arsenic would have to be applied to forest trees. This is an easy matter, given the appliances, labour, and a supply of water and arseniate. When it is a question of treating an area of 12,000 square miles of forest country, the enormous cost immediately puts the matter out of consideration. Contact poisons have suggested themselves as a mechanical means of destroying locusts gathered in large quantities on the trees. Captive locusts sprayed with ordinary kerosene emulsion, die after 24 hours, probably because they are unable to fly and dry the mixture off their bodies. The same occurs far more rapidly when sprayed with McDougal's Sheepdip (1 lb. to 3 gals. of water). Locusts in the field, sprayed with the latter mixture, are found dead in 12 hours if sprayed in the evening, and when sprayed in the morning they die in the course of the day. Pure kerosene sprayed on them has the same effect. As a substitute for Sheepdip, McDougal's Sanitary Fluid at 1-20 has been used, and locusts so sprayed die in the course of the day This contains crude carbolic (as creosote oil) and the carbolic is the killing agent in all probability.

Kerosene is the only other substance that suggests itself as a useful killing substance.

The contact poisons commonly used for insects include kerosene, rosin, tobacco, sulphur and lime, soaps ; carbolic cannot as a rule be applied to plants but is a good contact poison, as is creosote. Of the standard insecticides, crude carbolic preparation, sold as "Sanitary Fluid" combines efficiency and low cost. As a result of investigations with different forms of crude carbolic preparations, the ordinary "Sanitary Fluid", a dark black or green soapy fluid, has been found to be the best. Kerosene and rosin preparations are effective at great strength, but are tedious to prepare and costly. Sanitary Fluid costs about Rs. 10 per 5-gallon drum, sufficient to make 150 to 200 gallons of wash as actually applied. It is readily obtained in large quantities. The question of using insecticides for locusts is discussed elsewhere ; no advantage is likely to be derived from their general use. Vapour poisons are entirely out of the question either against hoppers or flying locusts.

PART IV.

THE LOCUST PROBLEM.

The Bombay Locust in September 1903 probably occupied an area of not less than 25,000 square miles ; during the winter months it was concentrated in an area of 12,000 square miles and it then dispersed over an area which cannot be less than 140,000 square miles. To deal with a migratory insect that moves over such areas of country is not a light matter, and the experience of this outbreak will be of great value when the next commences."

In all probability, there will be no warning of the next outbreak until the flying locusts emerge as they did in September 1903. During the rains of 1903, there must have been numbers of hoppers throughout the area in which the swarms originated and there is no more likelihood that the hoppers will be seen in another year than they were in 1903. In discussing the general measures possible against the locusts in another year, it is convenient to commence with the flying locusts as they come out of the crops. Wherever locusts are found in September or October, whether in Bombay, Central Provinces, Madras or Central India, the most accurate information possible should be obtained as to the size of the swarms and their movements. During 1903, the swarms came largely from South Gujarat, with a contingent from Goa and Khandeish ; in 1904, the eggs were laid and the swarms would have started over a far wider area, if the climatic conditions had been favourable to the eggs hatching. It is, therefore, not possible to say that the swarms will originate in any particular part of the country ; their natural and normal breeding place appears to be the forest region of the Ghâts and that neigh-

bourhood; in exceptional years they spread over a larger area, as they did in the early part of 1903, and again in 1904. If the swarms return, as they did in 1903, into the Ghât forest region, they have to be attacked there; whatever their movements, it will be important to know where they are and in what direction they move.

During September and October, little can be done; the villagers should be induced to come out and beat the swarms from the crops in the manner described on page 20. Continual harrying may drive the locusts from place to place, till they reach the forest regions, where at least they will not destroy the crops. They cannot be destroyed in these months on any large scale, and the one thing possible is to keep them moving, to drive them into waste lands, and worry them till they leave the fertile areas for the forests. During the cold weather, the method of destroying them at night can be followed wherever the locusts are accessible. Places like Mahableshwar and Satara form centres for this work, and in every village efforts should be made towards killing the locusts under the stimulus of a proper reward and an active officer. There are at least four months during which this can be done, when the locusts are concentrated in a smaller area and are perfectly helpless at night. After this comes the migrating period, during which nothing can be done except to attack them at night as before. The coupling season offers the last hope of destroying them before eggs are laid; there is little difficulty in collecting them by day and every pair of locusts then killed means one egg cluster less laid in the ground. The utmost care should be taken to compile accurate records of the places where the locusts lay eggs, that is, of the districts where locusts are at the coupling and egg-laying season. Though it is not generally possible to destroy eggs, it is possible to destroy hoppers, and no better or easier method offers itself of checking the locusts than that of destroying the hoppers. If large swarms of locusts are known to live till the coupling period and are then marked down, it may be possible to destroy hoppers on a large scale when they emerge later in the season and so

check every outbreak at the commencement. The action necessary amounts to—

(1) Note the movements and size of the swarms during the first migrating period.
(2) Urge the villagers to drive them out of the crops.
(3) Destroy them at night during the cold weather.
(4) Destroy them during the coupling season.
(5) Mark down the localities in which they couple and lay eggs.
(6) Destroy the emerging hoppers.

In view of the many printed papers issued by the Government of Bombay during the year, comment on these points and on their execution is not much needed. The experience of 1903-1904 has elucidated much, and notably certain practical points which would have been of great value had they been known before the outbreak of locusts.

In regard to the first point, the very practical caution of ascertaining the identity of the locust may be impressed. In 1903 the migratory locust was also passing through Gujarat and was confused with the Bombay locust. The past records bristle with difficulties and misconceptions due to the impossibility of accurately identifying the locusts or to the chance assumption that the locust in question was "Acridium so and so."

Various methods of carrying out the third point were advocated and tried. The use of fire in any form was eventually abandoned, as also the use of kerosene torches. Insecticides are extremely valuable when they can be applied, but the expenditure of large sums on machinery and insecticides, while useful for the protection of stations such as Mahableshwar, is not likely to solve the general problem. It has been shown that twelve men with insecticides destroyed ten times the number of locusts killed by hand with a large gang of labourers in far less time, and at far less cost; but the difficulties of transport and of water-supply, and the absence of men fit to carry out this work put this method beyond consideration. The method of killing locusts at night was fully successful at

Mahableshwar, and was largely adopted during subsequent operations in many parts of the Bombay Presidency.

During the coupling season, no special methods are needed. The offer of rewards, and the encouragement by village officers and mamlatdars should stimulate the people to collect the locusts and the only thing needed is a supply of bags in which to bring in the locusts.

The destruction of hoppers by means of bags and frames was tested on a sufficiently large scale to demonstrate its fitness for general use, and more complicated methods are not likely to offer any advantages. The Appendices contain papers relating to the measures adopted and their efficacy, which will be of value in the future.

The Permanent Habitat of the Locust.

The outbreak of locusts in 1903-1904 was an exceptional phenomenon due to conditions not fully understood. It is comparable with that of 1883, and we may anticipate such outbreaks periodically, though not at regular intervals.

It is not possible to say to what causes this outbreak was due. The natural increase of the locusts yearly would be fifty fold if none died. A single swarm alive in May would, if conditions were suitable, produce fifty swarms by the following October. It is thus evident that there are natural checks on the increase of locusts, as there are on the increase of all insects. These checks appear to be climatic conditions and parasites or enemies. The first is probably the most important and, perhaps, solely responsible for the fact that locusts cannot increase beyond a certain number, and is operative principally when the locusts reach a large number. The second is a permanently acting check, which is not wholly efficient and can never be expected to be. Natural checks of this kind act in waves, the great increase of the parasites or enemies producing so great a diminution in the number of locusts that automatically the parasites perish for want of food and the locusts again increase. We may expect an alternation of few and many locusts if we look to natural checks alone.

The matter cannot be fully understood until we have longer experience of the habitat of the locust. So far as our present knowledge shows, the Bombay locust is dependent upon forest areas for its food during the time it forms swarms (November to April). The forest areas of Kanara, Goa and neighbouring districts would seem to be its permanent habitat during this period in normal circumstances. In this region it commonly abounds in swarms. In other forest areas also it may frequently occur in swarms, but so far as is known these areas are confined to the Western half of the peninsula. In other parts of India it occurs in small numbers, being either carried in exceptional migrations as that of 1904 or normally breeding there. We can anticipate small swarms originating in any forest areas in Southern and Central India, but possibly the forest areas are not large enough or not suitable for the production of large swarms except on the Western Ghâts. Accepting the Kanara and Goa forests as the normal habitat, we know that in ordinary years, the locusts breed in open grass lands or waste lands in or near these forests, including Dharwar, Belgaum, Hyderabad, Mysore and Kanara. The new broods of locusts that fly in October appear then to return to the forests. In years of greater increase, the swarms in these forests appear to spread further afield, either for food or for breeding. They then occur in the Western Ghâts as far north as the Dangs and enter Gujarat. Whether they also go into Mysore, Hyderabad or Madras territory in any numbers is not known. This apparently occurred early in 1903, the locusts that arrived in the Dangs and Gujarat in April 1903 giving rise to the swarms of October 1903. In this case the first spreading of the locust swarms was followed by a large increase, due either to the absence of parasites and enemies, or to favourable climatic conditions. In other years it is possible that the spreading of locusts is not followed by large increase, probably owing to unfavourable climatic conditions. In this connection we may ask what happened to the progeny of the 1904 swarms which spread over so vast an area. We know the locusts laid eggs over a large area, though the

number that survived to lay eggs was not a large proportion of the original swarms. Actually, the swarms of 1904-05 were small, confined to a smaller area, and practically only in their normal habitat, the Goa and Kanara forests. How was it that the large number of locusts that were alive in June 1904 did not give rise to large swarms ? It is difficult to say ; we can accept the hypothesis that the climatic conditions of the large part of the area they spread over were not suited to egg laying and egg hatching. On the Western Ghâts and possibly in isolated parts of the Deccan, the rainfall was large enough to admit of (1) egg laying, (2) egg hatching, (3) the development of the young. Generally speaking, the rainfall was insufficient, and so far as experiments can guide us, insufficient especially for the development of the hoppers.

The writer's personal opinion is that a part of the hoppers died from lack of moisture. It was actually found possible to rear hoppers to maturity only in a very damp atmosphere. Such an atmosphere is normally found in the Ghâts, but not in many parts of the Deccan, Central Provinces and Central India, where the locusts spread to.

The monsoon of 1904 over a large part of Western India was light, and only in scattered places were the conditions suitable to the locusts. We may doubt if the conditions over a large part of the Deccan are ever suitable to locust hoppers in ordinary years, and we may perhaps look to this as the principle check on locusts. So soon as locusts become so abundant that they have to leave the Ghâts to breed, their increase is checked by the destruction of the young which hatch in unfavourable places.

This is at best a hypothesis, but one built on the available facts. There is no evidence that parasites or other checks accounted for the failure of the locusts to appear in vast numbers as they should have done in October 1904. The measures taken against hoppers were possible only in exceptionally wet localities from the very fact that hoppers were not found abundantly elsewhere.

In May 1905, locusts swarms again appeared in Belgaum and spread out from the Goa and Kanara forests into Dharwar,

Belgaum and Bellary. There were none in the Ghâts of Thana and Ratnagiri, and the locusts had apparently been reduced to their normal numbers and were behaving normally again. The occurrence of the locust plague over a large area would appear to depend upon the behaviour of the swarms of the Kanara and Goa forests. If these become large, spread over a large area and can breed successfully outside their normal breeding places, we may look for another locust year. But it would seem to require exceptional conditions and we may regard the size of the swarms of the Kanara and Goa forests as the indication that such a thing is likely to happen.

PART V.

THE BOMBAY LOCUST AND ALLIED INSECTS.

THE nomenclature and classification of Indian grasshoppers and locusts is in a backward condition, the actual scientific designation of various species not having been settled. Authorities on this group differ in the species to which they assign the Bombay locust. Specimens in the Indian Museum were assigned by Mr. de Saussure to *Acridium succinctum* L.; Mr. W. F. Kirby of the British Museum regarded specimens sent to him as being *Acridium rubescens* Walker. For the present, it is necessary only to have a scientific designation as accurate as our present knowledge will allow, and the name *Acridium succinctum* L. is taken as representing the best name available. *Acridium* is a genus closely allied to *Schistocerca*, and these two genera include the greater number of the true locusts. They form a part of the family *Acridiidæ*, or short-horned grasshoppers, of which some 120 species are named in the Indian Museum and at least one thousand species probably occur in India. Many species have been found in the course of this investigation, and only the commonest species of India can be said to be even named, far less known. The family *Acridiidæ* includes all those insects known as locusts, which term is frequently misused. A locust is an Acridiid, which multiplies to a large extent, forms swarms and migrates over large areas of land; a grasshopper is an Acridiid that does not form swarms which migrate. The essential thing in the locust is the migrating swarm; there is no structural difference, it is simply a matter of habits and life history. Restricting the term locust to its proper sphere there are in India two locusts at least; the North-West or

Migratory locust, *Acridium peregrinum* Oliv. and the Bombay or Western India locust, *Acridium succinctum*. L. There are doubtful locusts, and the main mass of Acridiids are grasshoppers pure and simple, without the swarming or migrating instinct.

In fact *Acridium succinctum* itself is a grasshopper pure and simple in most parts of India, where it occurs sparingly and not in sufficient numbers to form swarms.

In any year there are probably enough of the spotted grasshopper, or the rice grasshopper, or the painted grasshopper to make quite large swarms and do much damage were they all together in one place and moving about, but as they are scattered over India and stationary, their ravages create less notice. The immense swarms and the extraordinary movements of the Bombay locust give it an enormously exaggerated importance; it fills the imagination and appeals to the human mind. The damage done by the locusts is probably far less than that done yearly by two pests of cotton (*Earias fahia* and *E. insulana*) or by the mothborer in cane, and sorghum *chilo simplex*). In point of numbers the locusts are far below the probable numbers of these pests in any one year; in point of destruction and actual loss of crop, the ordinary pests are far ahead of the Bombay locust in its worst years.

The Bombay locust is readily confused with other species, especially as it may occur in the same place and at the same time in two or (during the coupling season) in three distinct colour forms. It is no easy matter to put down on paper the differences between closely allied species and practically impossible to do so in language understood by everyone. Distinctions based on the fact that the pigment in the wings is, or is not, situated in the wing substance are useless, as also is such a distinction as a streak of colour below the eye. The number of species with which the locust may be confused is, however, small if all considerations are taken into account. One may at once eliminate all species with a length of less than two inches and which are not at least $\frac{1}{2}$ inch across the body. This eliminates the greater number of the 120 known and the many

unidentified species of grasshoppers. Remembering that green never enters prominently into the colour of the locust, and that all uniformly coloured specimens, unless bright red, cannot be the Bombay locust, eliminates all but a very few species. Thus the migratory locust is often uniformly purple red, has fore wings spotted in small spots from base to apex, and has small indented lines round the neck. The large painted grasshopper (*Poecilocera picta*) is brilliant blue green and yellow; the hooded grasshopper (*Seratodus Monticolles*) is green; the very large *Acridium melanocorne* are uniformly dull red brown or brown in colour. All grasshoppers known in the Western and Central part of India can be eliminated on size and colour except one, the so-called spotted grasshopper, *Acridium æruginosum* Burm. This has the spotted wings, the stripes of colour, the same dimensions as the Bombay locust and is closely similar in appearance. Minute structural characters of the male and female external genital organs are quite valid evidence for the entomologist but cannot be clearly shown on paper. The spotted grasshopper is yet a very characteristic insect, coloured in dark brown and white, with wings conspicuously blotched with black and with a conspicuous white blotch at the side of the neck. It is more robust and strongly built, and never varies in colour. This is the insect most commonly confused with *Acridium succinctum*. Probably nothing but an actual comparison of specimens of both species would be sufficient to show the very characteristic but small differences in these two species. Specimens of the two should be kept side by side in every district office, and if the specimen is not *Acridium æruginosum* it is likely to be one of the many coloured varieties of *Acridium succinctum;* that is, if it is not eliminated by the characters given above. The following are the species that can be found readily and may be confused :—

Acridium peregrinum Oliv. (Pl. VIII, IX, fig. 2 and X, fig. 3.) The North-West or Migratory Locust. This entered South Gujarat from Kathiawar early in December 1903, and swept eastwards in swarms. It is liable to visit any parts of Central and

Northern India. It is uniformly reddish purple or yellow in colour. The forewings are spotted with small spots from base to apex. There are no lines of colour along the neck, or on the head ; there are indented lines (fine grooves) round the upper part of the neck. It is slightly smaller than the average female Bombay locust.

Acridium æruginosum. Burm. (Pl. VIII, IX, fig. 3, and X, fig. 5.) Common over Central and Southern India. Found in all stages at various times of the year. Probably never gregarious, and having no definite periods for reproduction. The large white blotch on the side of the neck, the conspicuous large black blotches on the wings, the general white and black colouring and more robust build easily distinguish it. Males are conspicuously smaller than females.

Acridium melanocorne. Serv. (Pl. XII, fig. 3) and similar species. The large solitary grasshoppers, uniformly red brown or brown in colour, larger than the Bombay locust, are easily marked from the locusts. They are not common but occur all over India.

Poecilocera picta. (Pl. XI, fig. 4.) The painted grasshopper, with stripes and lines of brilliant blue-green and yellow, common on the 'Ak' plant, Calotropis spp.

Teratodus monticollis. The hooded grasshopper ; a sharp hood rises over the body, in a semi-circle, being the immensely-produced prothorax. Green or dry grass colour. Very narrow across the body.

Demodocus robustus. (Pl. XII, fig. 1.) This and other species of *Demodocus* are to be recognized by a flattening of the neck, with two stripes of colour at each side of this flattening. On looking down at a Bombay locust in the dry grass-colouring, one sees one large stripe of yellow from head to wings. On looking at a Demodocus one sees two, curving from head to wings, with a flat dark space between. This is unmistakeable.

Hieroglyphus furcifer. Serv. (Pl. VIII, fig. 4, and Pl. X, figs. 7 and 8.) The rice grasshopper. Uniformly green or browny yellow in colour, with little black lines on the sides of the neck. Smaller than the locusts. This is the

familiar Pha-Pha of the Central Provinces, of Gujarat, Belgaum, Mysore and other parts of India. It occurs chiefly in rice land or other wet land and is very widely distributed in India. As this insect lives in its winged stage only from August to October, it is confused only with the first flying locusts.

Practically all other grasshoppers known to occur in Western India are eliminated by size. Many specimens and many species have been collected in the course of this enquiry, and the species of this group found in Western India are fairly well known. It is believed that except the above no other species is likely to be confused with this locust. The earlier stages of the various grasshoppers are not invariably distinguishable, and many varieties of grasshoppers, old and young, were sent in for identification.

One rule that should be borne in mind is that *every winged insect is full grown.* A grasshopper, however small, that has wings, cannot grow any more and cannot be the young of a larger insect. This rule is without exception, and one may instantly reject as locust hoppers all insects with wings. Beyond this, the subject becomes involved and complicated by the great number of hoppers which are found during the rains. As a rule these cannot be identified until they are reared to the perfect insect. In years to come, it may be possible to rear and study large numbers of hoppers and so be able to identify our common kinds. At present this is impossible and a few species only are accurately known in the hopper stage. One must remember that hoppers pass through at least five stages before becoming winged, and in each of these undergo changes of size and usually of colour. A description of a hopper in the first stage would not fit the same hopper in another. For instance, the hopper of the rice grasshopper emerges in June as a small dark insect with a light green stripe down the back. In the next stage it becomes green, and remains green for three stages. In the fifth stage it has the green rudiments of wings, and the black lines on the neck, with a tinge of reddish brown on the legs, the posterior half of the large leaping legs

blue. There are here three very distinct looking insects, all stages of one insect.

The young of the painted grasshopper (*Poecilocera picta*) is very different from the perfect insect, the ground colour yellow with stipples and fine lines of black and vermilion spots. Only in the last stage but one does the characteristic blue-green and yellow commence to appear. The young of the hooded grasshopper is green, with the conspicuous development of the hood already showing. The young of the spotted grasshopper is uniformly green (Pl. XI, figs. 1-3) with the posterior edge of the neck flesh colour. It is at once distinguished from the young of the Bombay locust.

As size is of no value as a criterion of the young Bombay locust, one cannot distinguish it from other hoppers. Descriptions of every stage are reproduced above; if one wishes to ascertain whether a certain hopper is that of the Bombay locust, measure the hopper, find the stage of the locust that is that size, and see if the description fits the hopper. Hoppers almost identical with those of the Bombay locust are common and would deceive all but an expert trained to discern small differences. It is advisable to place no reliance on the determination of hoppers but to send the specimens for accurate comparison with guaranteed specimens of the hoppers of the Bombay locust.

The chief distinction that marks *Acridium succinctum* is the curious life history. Most insects emerge in the winged state with mature reproductive organs, live a longer or shorter period in this stage and lay eggs. Many pass through the cold season and dry weather in a resting stage, the supply of food being sufficient only in the rains. Others reproduce at different periods of the year, one brood succeeding another as long as there is food. In the family *Acridiidæ*, some are many-brooded, reproduction taking place at different times of the year : some are apparently two-brooded, and this includes the migratory locust, *Acridium peregrinum*. The Bombay locust is one-brooded, as is the rice grasshopper and some others. For one-brooded insects, which find food for their

young during the rains, the long period from November to June has to be passed through, and the greater number of insects pass this in some resting stage; the rice grasshopper lays eggs in October which hatch when the first rains fall, and so lives eight months in the egg stage. The most striking fact in the Bombay locust is its habit of living eight months as a full-grown insect, waiting until the near approach of the rains before the reproductive system develops.

APPENDIX A.

THE ACTION TAKEN AGAINST LOCUSTS IN THE BOMBAY PRESIDENCY.

As already stated, the locusts appeared in large numbers and commenced to fly in October 1903. As they left the northern part of the Presidency and moved south, no measures could be taken against them in the fertile district of Gujarat and no action was taken by the Government.

In January, when the swarms were concentrated in the Ghâts south and east of Bombay, the locusts again attracted attention from the very evident damage done to the forests but no action was deemed necessary; in February the Superintendent of Mahableshwar reported that the station was being defoliated and that the locust swarms should be checked before the forests round the station were entirely stripped. Experiments were then made against the swarms but no action was taken on a large scale. The matter was, however, regarded more seriously as dissection of locusts showed developing ovaries, and three Assistant Collectors were put on special duty to watch the movements of locusts throughout the Presidency and to spread information among the people as to the locusts and as to any measures found available for destroying them. These officers remained on this duty until October.

During April and May, the question of locust destruction was taken up, and in different districts action taken immediately. Information was diffused as to the locusts, rewards

were paid for killed locusts and an effort was made to deal with swarms at night. The following district orders were issued in Kolaba District:—

DISTRICT ORDERS.

No. 2497, dated 6th May 1904.

In their Resolution No. 3268, dated 29th April 1904, Revenue Department, Government have directed that steps shall forthwith be taken to destroy adult flying locusts. Only a very short time now remains during which this can be done, and the work must therefore take precedence of all other work in any "saza" or village where locusts appear.

2. When a swarm of locusts is observed in the afternoon preparing to settle for the night, the villagers must at once send information to the talati, if there is no resident kulkarni. The talati (or kulkarni) will thereupon leave any other work he may have in hand, and proceed at once to the village, where he and the patel will require the people to turn out and destroy as many locusts as possible after they have settled at night and before they begin to fly in the morning. They may be killed by being knocked down with branches or cloths; or they may be caught alive, thrust alive into cloths or bags, and plunged into boiling water; or it may be found possible to apply lighted torches on the ends of long bamboos to the branches on which the locusts have settled, thus singeing their wings and either killing or crippling them.

3. In the morning, when the locusts begin to move and it is no longer possible to approach them without disturbing them, the dead locusts should be collected and weighed. They are to be paid for at the rate of ½ anna per seer of locusts. The talati (or kulkarni) will make out a list showing the amount of reward due to each person (or to the villagers collectively, if that method of payment should appear expedient) and send it to the Circle Inspector, who will at once disburse the amount from his permanent advance. Similar procedure should be adopted to pay for cost of oil for torches, &c.

4. Circle Inspectors must keep their permanent advances constantly recouped, and apply for a temporary increase of advance if this is found necessary. They must arrange to obtain prompt information of the appearance of swarms in their Circles, and to visit at once the affected spots, discontinuing all other work for the time. They will afford the talatis all possible assistance, will impress on the people the Commissioner's orders that no remission for damage by locusts will be given where the people do not make strenuous efforts to destroy them, and will note for future guidance those villages where the people are backward in this matter.

5. Sub-divisional Officers, Mamlatdars and Mahalkaris will further the work to the best of their ability. They can disregard all routine inspection work for the rest of the season.
6. Operations within forest limits will be ordinarily undertaken by the Forest Staff ; but the people must be made to understand that they must turn out to render assistance whenever called upon by the Forest Officers of whatever grade.
7. So much for what can be at once done with respect to adult locusts. As to organisation for further action, the Sub-divisional Officers should now submit at once the reports called for in this Office No. 1976, dated 13th April 1904.
8. The Assistant Collectors, who have been placed on special duty; will be visiting the affected taluks. Their orders must be regarded as having the same authority as those of District Officers ; and subordinates of all Departments must, when on tour, take every opportunity of impressing on the villagers the instructions given by those Assistant Collectors in the matter of locust destruction.
9. Special reports should be made by Mamlatdars and Mahalkaris to the Assistant Collectors on special duty ; also to this office, when the locusts are observed to be beginning to copulate : and a reward of rupee one may be offered for the first correct information of the discovery of locusts eggs within the limits of a village.

This work continued in various parts of the Presidency under the advice of the special officers on locust duty or of the District officials. The following instructions were issued by Mr. T. R. Bell, Assistant Collector, on locust duty :—

Copy of detailed instructions as to the methods of destroying flying locusts, prepared by Mr. Bell.

The only time during which the work can be carried on is at night. The locusts begin to settle down in the evening and after a time become torpid, unless the night is very warm. The best time to begin the work is at 2 A.M. and it should be continued till sunrise or so long as the locusts do not fly away.

The methods of killing depend a great deal on circumstances. The details given below will, however, be a guide.

As a rule the locusts will have settled on trees for the night. If these trees are fairly large with even ground underneath, devoid of shrubs, the best way is to use a gang of men as follows :—A gang should consist of 20—25 men and women under an overseer, and several gangs may operate on the same swarm. Each gang should be in three sections of seven or eight men and women each. One man will climb the trees and shake the branches with great force when the locusts will fall down, or he may use a long pole with a hook at the

end and shake the branches with the pole. Another man must be provided with a torch of some kind to give light. The other five or six men and women will beat the locusts which fall down to the ground with brooms and stampers of wood. Women use the brooms better than men. Generally also the brooms are more effective and there should be at least three or four brooms in each section of beaters. Each overseer will have three gangs like this and he should take care to keep them working regularly forward in a straight line. Other beaters should take the same precaution. The work will go on all right from 2 A.M. or 3 A.M. until sunrise and by this time a considerable area of jungle will have been covered.

In the morning a large number of locusts will be found dead on the ground and the beaters should now start where they began work and collect these in bags. But a great number of locusts will only be stunned by the beating of brooms, and when morning comes they will be seen to have climbed up small shrubs and plants and up the lower parts of the trunks. These should be collected by hand at the same time and placed in bags. This is most important as the larger portion of the locusts will be killed in this way. When a bag is nearly filled, it should be plunged for some minutes in a pot of boiling water—which has previously been put in a suitable place—and when the locusts appear to be dead, the bags should be emptied out and the work begun again. This work should be continued till the locusts begin to fly away.

It will sometimes be better to get a fresh gang of workers to gather the locusts in the morning, as the men and women who have been working during the night lack energy in the morning, and the gathering of the stunned locusts is important.

After the work is finished the locusts can be weighed and the rewards paid.

It is much more effective for a gang to work under a good supervisor. The reward will then be distributed among all equally. Many more locusts will be killed and more money earned in this way than if each rayat worked for himself. It may sometimes be cheaper to pay each man a fixed sum for the night instead of paying a reward according to scale, but as a rule payment by results is best.

Instead of beating the locusts that have fallen down, it is sometimes a good plan to sweep them into heaps and have them crushed with stampers, or they may be swept in this way into a bag. This can only be done where the ground is fairly flat.

If the ground is rough and uneven and also where there are many shrubs, stampers are of no use and only brooms should be used.

Brooms can be made of thin bamboos. The part of the broom used for sweeping should be broad and flat so as to give a large striking surface. Small branches and twigs of trees make good brooms. The leaves and small twigs soon get knocked off, but if two or three leafless brooms are tied together, an excellent beating broom will be formed.

Where the trees are low and the ground uneven or covered with shrubs, beating will not be practicable. The trees should be shaken as before and the locusts that fall down should be gathered by hand and placed in bags. The locusts are then killed by plunging into boiling water.

If the ground is covered with low shrubs on which the locusts are settled, they can be collected in handfuls off the shrubs and put into bags.

Sometimes a large isolated tree is covered with locusts. It is then a good plan to hold cloths underneath the tree. When the tree is shaken, the locusts fall into the cloth, when they can be easily crushed.

A great deal depends on good organization. A well-organized party of 25 beaters is more effective than disorganized beaters. Experience has shown that the best way is to pay the beaters according to results.

During June the locusts started egg laying, and preparations were made for collecting eggs and destroying hoppers. Rewards were paid for coupling locusts, for eggs, and later for hoppers. The rate for locusts during the coupling season was raised from half an anna to four annas per seer, and Rs. 10 was offered for the first information of egg laying in each village.

On the whole few eggs were found, but a fair number of locusts were captured by hand during the coupling period and probably as much good was done at this time as at any period. By the first July, egg laying was stopping on the Ghâts and the next step was to destroy hoppers. The sum total of locusts destroyed in the Northern Division of the Presidency is put down as 52,000 seers (less than 1,000 cwts.), in the Director of Agriculture's letter dated the 14th July. In a later letter, the weight of eggs destroyed in two parts of Kolaba District is put down at thirty-seven and a half maunds (over 24 cwts.), but this is the only record of extensive egg destruction. The destruction of hoppers was then undertaken partly according to the method described, partly in other ways. Rewards were paid for hoppers and it was found that very many insects which were not hoppers were included. The rates for small hoppers varied and an endeavour was made to pay so that each man could earn a fair day's wage. As much as two rupees per seer for small hoppers was paid but this was steadily reduced as the hoppers grew bigger.

The following extracts are of interest as giving glimpses of the action generally taken throughout the infested localities :—

Letter from the Director of Land Records and Agriculture, No. A.—4189, dated 14th July 1904.

"5. The reports regarding the several districts are summarised below :—

Gujarat	Free, except the Panch Mahals where locusts are said to have deposited eggs in several localities. (It may be noted that last year also locusts bred in the grass lands in the Panch Mahals.)
Khandesh	Widely but sparsely infested, the locusts being in a somewhat backward stage.
Nasik, Poona and Satara	Western portion seriously infested.
Nagar	Practically free.
Thana and Kolaba ..	Hilly talukas seriously infested.
Ratnagiri	Northern part infested. Southern part practically free.
Sholapur	Practically free.
Bijapore	Reported to be free.
Dharwar	
Belgaum	
Kanara	
Kolhapur	

"7. In the Northern Division 52,000 seers of locusts are reported to have been destroyed in all, of which in two weeks 10,000 seers were destroyed in the Mokhada Peta, where the Mahalkari is reported to have organised operations with vigour and intelligence."

Letter from the Director of Land Records and Agriculture, No. C.—322, dated 6th August 1904.

"In continuation of my letter: No. A.—4189, dated 14th July 1904, I have the honour to submit a further report regarding locusts.

"2. Except in the Khandesh District adult locusts appear to have now ceased to exist. During the week ending 16th July, nearly 10,000 seers of adult locusts were destroyed in the Northern tract, of which more than two-thirds were destroyed in Khandesh.

"In this district the hill-tribes having lost their nagli took to egg collection with vigour, and the conditions being favourable, 37½ maunds of eggs have been destroyed. On Mr. Lefroy's estimate of 100,000 eggs to a seer, 150 millions have thus been destroyed at a cost of Rs. 1,354."

Letter from the Director of Land Records and Agriculture, No. A.—5902, dated 26th September 1904.

"In continuation of my letter No. C.—322, dated 6th August 1904, I have the honour to submit a further report regarding locusts.

"2. Locusts' eggs ceased to be found after the middle of August. The only tract where measures for their collection met with any success was in Northern Kolaba where over 80 maunds were destroyed.

"3. The area infested by hoppers includes nearly the whole line of the Ghâts from Sangameshvar northwards, with the country adjoining on the east and west. Hoppers are also found in considerable numbers over most of the Khandesh District.

"The hoppers are not increasing in size as rapidly as might have been expected. Individuals are as a rule under an inch in length and give no indication of being ready for flight soon. They have not yet caused any serious damage to the standing crops, but in places it appears that they are now attacking the leaves and soft unripe grain of various crops.

"4. Measures for the destruction of the hoppers were in full operation by the middle of August. As the hoppers do not develop the gregarious instinct until after they assume their wings, it has been found impossible to drive them in a special direction. Unlike the locust of North-Western India they cannot therefore be dealt with on an easily organised plan. The only method of dealing with them, which has met with any success, is to catch them in large bags which are dragged over the ground. The method is slow and difficult.

"By the 3rd of September, 193 maunds of hoppers had been destroyed in the northern tract, of which four-fifths were destroyed in the Thana District. Up to the same date 85 maunds had been destroyed in the central tract. The ordinary cultivator shows no inclination to take part in the work of destruction which has been chiefly carried on by the wild tribes and low castes for the sake of the rewards."

Letter from the Collector of Poona, No. 9855, *dated* 30*th September* 1904.

"In continuation of this office letter No. 9537, dated 22nd instant, asking for a further grant of Rs. 7,500 for the destruction of the locust hoppers, which was sanctioned under the Secretary to Government's memorandum No. P.—318 of 28th instant, I have the honour to report that the killing of locust hoppers is now progressing vigorously throughout the west of the district, and I am receiving large indents for money from the Mamlatdars of Haveli, Khed, Junnar and Maval. These have practically exhausted the last allotment of Rs. 7,500 and it is now necessary that further funds should be provided.

"2. The supply of hoppers being very large and the energy of the people, now that weeding and transplantation operations are over, having been readily diverted to locust catching as a means of earning money, it seems to me highly probable that the sums payable as rewards will continue for some weeks longer to be very considerable.

"3. I have reduced the rate payable for hoppers from Re. 1 per seer to annas 8 per seer, with effect from to-morrow, October 1, but even at this rate, which is at present perfectly reasonable, I anticipate a heavy demand."

Letter from the Collector of Satara, No. 7511, *dated 1st October* 1904.—

"2. The previous allotment of Rs. 4,000 has been almost spent. Hopper locusts are now found in the three talukas of Javli, Satara and Patan, and in the Shirala Petha. They are found in very large numbers in the forest villages in the Koyana and Salshi villages of Javli. The amount now asked for will not be spent unless it is found to be actually required, but there is every probability that it will be needed, as several of the officers conducting the operations are applying for fresh allotments, and I have had to raise the price of a seer to secure labour."

Letter from the Collector of Ahmednagar, No. B.—4814, *dated 6th October* 1904.

"I have the honour to inform you that the sum of Rs. 3,000 placed at my disposal for the destruction of locusts in this district, as per paragraph 1 of Government Resolution No. 3268, dated 29th April 1904, Revenue Department, is nearly exhausted. The work of killing locust hoppers is at present in full swing in the Akola Taluka. I have therefore the honour to request that you will be so good as to move Government to sanction by wire an additional allotment of Rs. 2,000 to this district."

Letter from the Collector of Ratnagiri, No. 4095, *dated 4th October* 1904.

"3. Mr. Mackie writes as follows:—

'The method of catching hoppers by hand is now in general use, and from experiments which I have had made in Khed appears to be more effective than any other.

'A very appreciable diminution in the number is now discernible. In my last report I referred to this in regard to several villages in Khed. Round about Palgad in Dapoli Taluka, I have personally inspected several villages formerly much infested, and find that the hoppers have now grown quite scarce comparatively. The present campaign, I think, we may say, is proving successful.

'At the same time, the Mamlatdar of Khed reports that hoppers are beginning to fly in some cases. This ought not to be—they ought to have been killed off—and I have issued instructions in accordance with your No. S. R.—101, dated 20th September 1904, that all fields which have not been properly cleared should be carefully noted. I have also authorised the employment of day labourers on a guaranteed minimum wage in order that labour may be employed in the places where it is most needed. So long as the reward earned exceeds the wages, the reward is paid. Otherwise the promised wages are paid, but when once this latter has been found necessary, the question whether it is necessary to continue day labour is to be considered. No such case has arisen yet. In Dapoli men can be engaged freely at two annas per day.

'Mahars, Kunbis, and Katkaris compose the great bulk of the people employed in destroying the hoppers.'

Letter from the acting Collector of Ratnagiri, dated 11th September 1904.

3. But in a great measure the need for employing paid labourers has itself diminished as the rate of reward now given has given a great impetus to the work, and in every affected area large quantities are daily destroyed and brought up for reward. Payments are made at several centres* in each taluka besides the taluka or Mahal stations, by the charge Superintendents or by local committees consisting of the schoolmaster, Khot, Police Officer, Police Patel and such other respectable persons available on the spot. These committees are working very satisfactorily. It is indeed due to the multiplication of payment stations that the work of catching locusts hoppers has now been taken up in earnest by the labouring classes, as formerly owing to the long distances people had to go for payment, they did not care to exert themselves even when the rate was increased.

* 5 in Sangameshvar.
6 in Chiplun.
7 in Khed.

4. The allotments (Rs. 11,000) made by Government have all been expended and I have had to wire to the Chief Secretary to Government for an additional allotment of 8,000 rupees.

5. As to the present rate, 1 rupee per seer (2 lb.), all my assistants recommend that it should be continued for the present and from my observations I agree with them. Now that their number is getting reduced, it is increasingly difficult to get at the hoppers in the crops. And then their growth is fortunately slow. Several experiments made here to-day with hoppers from different parts of the taluka gave the following results (approximate) :—

Minimum number per seer (2 lb.)	...	...	...	2,000
Maximum number per seer (2 lb.)	...	..	...	3,900

On this point Mr. Mackie writes as follows in his report dated 8th instant:—

"2. No doubt in some few villages a man might make four or five annas a day but I have made several experiments and personally inspected the state of things in several villages which may be regarded as average and there I find that the present rate is not excessive. A man by hard work can only make two or three annas a day.

"3. One of these experiments has just been completed. Two men working a dhotar caught 17 tolas in five hours. I noticed that some of the hoppers had wings reaching to the tip of the tail and this morning in another village I found they were growing so big as to be able quickly to get over the top of the screen I was employing. In view of these facts nothing that would in any way cause relaxation of the efforts at present being made should be done.

"4. The Mamlatdars are of like opinion. In most parts of Depoli in fact the Mamlatdar reports the present rate does not adequately reward the exertions necessary.

"6. The standing crops have not so far been much damaged by hoppers, but owing to the destruction of seedlings by locusts in the commencement of the rains, considerable areas (chiefly nagli) have remained unsown. Inquiry about these is proceeding with a view to ascertain whether suspensions or remissions will be necessary.

Letter from the Collector of Kolaba, No. 7116, *dated* 22*nd October* 1904 :—

"In continuation of this office No. 7000, dated 17th instant, I have the honour to inform you that since writing that letter I have had considerable demands for funds for destruction of locusts from most talukas, but more particularly from Karjat.

"2. In this taluka I have now reduced the rate of reward to four annas per seer of hoppers, and I do not think that the lowering of the rate will reduce the number brought in as the hoppers are growing rapidly. I shall shortly lower the rate similarly in other talukas.

"3. I have now gone carefully into the figures and I think that a further allotment of Rs. 4,000 in addition to that asked for in this office number above quoted will probably meet all requirements up to the time of completion of the reaping of the crops, after which I hope it will be possible to suspend operations.

"4. I therefore request the favour of Government sanctioning an allotment of Rs. 6,000 in all, *i.e.*, Rs. 4,000 in addition to that already asked for and not yet sanctioned.

"5. The reason for the differentiation between Karjat and other talukas is as follows :—

"On taking charge of the district on 1st instant I found a note from my predecessor, Mr. Bonus, to the effect that in his opinion the then existing rate of eight annas per seer might shortly be lowered to six annas. I issued orders on 14th to lower the rate to that extent and had scarcely done so when I received a report from the Mamlatdar of Karjat recommending a further reduction to four annas for that taluka and stating that such a reduction was not likely to prejudicially affect the rate of destruction. I reduced the rate for Karjat accordingly to four annas and am now awaiting reports from the Divisional Officers whether a similar reduction can now be made in other talukas without interfering with the work.

"6. It has just been reported to me that locusts hoppers killed in Mahad are being taken into the Khed Taluka of the Ratnagiri District owing to the present rate of reward there being higher. As it is obviously desirable that the rate of reward should be the same in adjoining talukas of different districts, I have informed the Collectors of Thana, Poona and Ratnagiri of the rates prevailing on their borders in this district and shall inform them of any alteration in those rates. I have requested them to reciprocate the information."

Letter from the Collector of Ratnagiri, No. S.N.—121, *dated 13th October* 1904 :—

"In reply to your No. S.R.—94 of 12th instant, inquiring how long expenditure on locusts will continue, I have the honour to refer you to my weekly report No. 4095,* dated 4th instant. As I have already reported, hoppers in the early stages of growth are still found almost everywhere and but few full-grown ones are met with, testifying to the undoubted success of the operations so far. It seems to me, therefore, that the destruction of hoppers must continue until they are all disposed of, or at any rate until all standing crops have been reaped. I estimate that this will not be before at least three weeks more and probably four. Of course it would be disastrous to suspend the operations at this stage although the amount paid as rewards may have exceeded any anticipations. It would be equally disappointing should swarms of locusts arrive from above the Ghâts and destroy what has been successfully saved so far. Within this week there have been persistent rumours that locusts have arrived in that tract, and I have asked the Political Agents, Kolhápur and Sávantvádi, to inform me should it be so. I have no information either as to whether similar measures for the destruction of hoppers are in progress in the Native States above the Ghâts. I mention this as I have heard that in at least one State, *viz.*, Bávda, bordering on the Rájápur Táluka, nothing is being done although there are hoppers there. I must say, however, I have not been able to verify this information."

Letter from the Director of Land Records and Agriculture No. c.—651, *dated* 28*th October* 1904 :—

"In some tálukas of Thána, the locusts have already begun to fly, and the Collector of Ahmednagar informs me that swarms are reported to have migrated from Thána into the Akola Táluka.

"5. It appears that when the weeding and transplanting operations were over, the liberal rates of reward sanctioned succeeded in inducing the cultivators to undertake the destruction of hoppers with a considerable amount of energy.

"It is not, in my opinion, possible to judge of the effect that this destruction has had upon the plague, until some information is obtained as to the numbers and extent of the winged swarms.

"6. But even if it be found that the numbers destroyed bear an inappreciable proportion to the numbers which have survived, a benefit of considerable importance will have been secured by the grant of the rewards, for the cultivators, who have received them, are probably the men who will suffer most severely from the depredations of the locusts, and the payments made to them may be regarded as a measure of State relief.

"7. It is, I think, desirable that a record should be kept of the movements of the winged swarms, for last year little attention was paid to them at this stage of their development: and their life history is still incomplete. I have the honour, therefore, to suggest that all Collectors be requested to forward a weekly report of the areas in which locusts swarms are observed, of the general direction of their movements and of the damage which they effect, to Mr. Knight at Poona.

Summary of Táluka reports showing the progress made in the destruction of hoppers.

Name of district and táluka or petha.	For week ending 16th October 1904.		Total.		Remarks.
	Weight of hoppers destroyed.	Amount paid as reward.	Weight of hoppers destroyed.	Amount paid as reward.	
Poona.	Mds.	Rs.	Mds.	Rs.	
Mával ...	28	562	34	690	Hoppers have now reached the final stage and will soon begin to fly. Damage so far slight, though the hoppers have commenced to eat ears of corn and leaves in some places.
Haveli ...	100	2,000	450	14,650	Every week about 100 maunds destroyed. Hoppers still in their infancy, hence no damage to crops.
Mulshi Petha ...	28	567	55	1,294	Hoppers about 1½ inches in length and destroying nágli and wari crops.
Khed ...	120	3,823	220	7,430	Hoppers destroyed by poor cultivators and low caste people in Mávli villages in large numbers. Damage to sava and nágli. Rice crops also attacked but safe so far.
Junnar ...	13	260	55	1,605	Hoppers have reached the stage of young locusts though not yet able to fly, and eating grass and leaves of young crops. Damage so far insignificant.
	289		814		
Násik.					
Kalvan ...	½	4	1½	14	Slight damage reported from 2 villages on the borders of Surgána and the Dángs.
Igatpuri ...	2¾	27	2¾	27	
Peint ...	31	197	94	558	Insects still in the hopper stage. Damage so far not appreciable except that in some fields leaves of nágli have been eaten. 60 villages in the táluka infested.
Kolába.					
Roha ...	⅞	17	10	280	Kulkarnis mostly engaged in the work of destruction. Hoppers doing damage to rice crops in the Kolad Circle.
Pen ...	9	175	40	895	Hoppers now grown in size. Some of them reported to be bigger than the adult locusts that appeared last year. Hoppers now met with on crops only.
Mahad ...	18	369	152	2,535	Extent of damage cannot be ascertained at present.
Khálápur ...	7	135	18	416	Hoppers fully developed, though not strong enough to fly. Their colour turning brown. No damage to standing crops.
Mángaon ...	9	81	177	2,069	No damage to crops.
Panvel ..	...	...	3	90	Only 3½ seers of hoppers destroyed during the week ending 16th October 1904 and Rs. 1-12-0 given as rewards
	44		400		

"8. When the locusts have emerged into the winged stage, I would recommend that the reward be reduced to the rate in force in the spring of half an anna per seer.

"9. I have the honour to suggest that special attention should be given to observing their habitat during the winter. It is surmised that at this period last year they took refuge in the forests of Kánara, but no certain information is available. It is possible that the cold of these months may render them so torpid that if they are congregated in any accessible locality, effective measures may be devised for their destruction on a large scale."

Letter from the Collector of Thána, No. 12321, *dated* 15*th November* 1904 :—

"With reference to Government Resolution No. 7299 of the 26th September 1904, I have the honour to report as follows :

"2. Government up to date sanctioned a total allotment of Rs. 18,000 for this district for the destruction of locusts. Out of this allotment a total expenditure of Rs. 16,572-12-7 has been incurred up to the week ending 29th October 1904, of which Rs. 14,834-1-9 were spent in rewards, Rs. 1,721-10-4 in purchasing *zolis* for catching locusts and Rs. 17-0-6 in miscellaneous expenditure. There is thus now a balance of Rs. 1,427-3-5 available for expenditure.

"3. The results achieved with this money are that 7 seers of eggs, 589 maunds 38 seers and 74 tolas of locusts and 1,229 maunds 7 seers and 464 tolas of hoppers were destroyed.

"4. Measures are still being taken in Murbád Tàluka and Mokháda Petha. In other tálukas the hoppers have either totally disappeared or have become so large that they can now no longer be caught.

"5. Apart from some slight damage to seedlings, which was largely repaired by fresh sowing, the early crops have escaped, and as far as can be judged, the late crops will also be safe, with the possible exception of tur, peas and the like in the ghât tract.

"6. The people were at first sceptical and apathetic, but the personal stimulus of officers and the prompt payment of rewards at a reasonable but not excessive rate roused them to the work of destruction which was steadily kept up with all the interruptions of their ordinary work in the fields ; and the well to-do classes have helped with subscriptions for locust bags to the extent of Rs. 1,325, so that altogether the credit of the work, such as it is, must be given to all for seconding the efforts initiated by Government, which I believe are cordially appreciated in the district."

In October 1904 the locusts were winged and hopper destruction ceased. Winged locusts appeared in swarms in various places but evidently the bulk of the insects had been killed and there was no fear of the enormous swarms that emerged in 1903.

The swarms that did emerge in 1904 did little damage and passed into the forest regions. The following summary of the final reports is of interest :—

Summary of the reports of operations against hoppers.

DISTRICTS.	FOR THE WEEK OF THE REPORT.					TOTAL.		REMARKS.
	Number of talukas affected.	Number of villages affected.	Rate of reward.	Weight of hoppers destroyed.	Amount paid as reward.	Weight of hoppers destroyed.	Amount paid as reward.	
			As.	Seers.	Rs. a. p.	Mds.	Rs.	
Poona ...	2	14	4	3,164	*157 15 0	4,343	51,850	*Figures for Ambegaon Petha not reported. Report for week ending 17th December 1904. Subsequent report is blank as the locusts have disappeared from the district.
Ratnágiri ...	...	796	½	5,064	610 4 3	4,551	1,10,795	Report for the period from 20th November 1904 to the 30th idem. Payments of rewards stopped in the district from 1st December 1904.
Násik ...	1	3	2	1½	0 3 0	237	1,284	Report for the week ending 13th December 1904. Subsequent report is blank as the locusts have almost disappeared from the district
Kolába ...	1	1	½	11	0 5 6	527	10,911	Report for week ending 10th December 1904. Subsequent report is blank.
Ahmednagar	1	43	1	38	2 6 0	305	5,164	Report for week ending 26th November 1904. Further operations now stopped.
Thána ...	1	2	2	4	0 8 0	1,838	14,924	Report for week ending 26th November 1904 Subsequent report is blank as the locusts have disappeared from the district.
Sátára ...	2	26	2 to 6	2,400	472 0 0	1,450	5,636	Report for week ending 19th November 1904. Operations against hoppers closed.
Khándesh ...	1	4	4	35½	8 14 0	1	10	Report for week ending 19th November 1904. Figures for Taloda Táluka only.
Total ..	9	889	...	10,718	1,252 7 9	13,252	2,00,574	

Summing up the campaign against the locusts in the Bombay Presidency, it is evident that a determined effort was made to cope with the pest and that the excellent organisation that extends to every village in the Presidency was effectual in producing a very general action on the part of the people; that this should be so is remarkable in view of the intense apathy of the ryot, his objection to taking life and his disinclination to countenance anything new. The work was done by special castes, under the stimulus of rewards, but nothing would have been done had not the Government roused the general mass of the people to the necessity of action and the possibility of effecting something. The total destroyed is estimated by Mr. Knight as follows:—

4,152 maunds of adults equivalent to 66,432,000 individuals were destroyed or two-tenths of a per cent. of the estimated number.

One hundred maunds of eggs were destroyed representing 400,000,000 individuals, and 13,252 maunds of hoppers which at 1,000 per seer is 530,000,000, or a total of the young of 930 millions.

This number may be a very small proportion of the estimated total, but it is probably a very large proportion of what would have emerged in October had nothing been done. Especially so is this true of hoppers. Nearly every hopper that hatches probably becomes a locust, whereas probably not one locust in ten of those alive in the previous December lives to June and not more than one egg in two that is laid hatches. Hoppers killed are by far the most valuable item, and I think the estimate given of 1,000 hoppers per seer is far too low; a safe estimate is probably 2,000 per seer. Taking the average of all ages and size killed during the season and if we allow that 1,000,000,000 more would have emerged as locusts, that were killed as hoppers, we have a total of fifty large swarms destroyed by this one means alone. Fifty large swarms means a number similar to that which came out of Gujrat in 1903 and the money spent is well spent in preventing another year like that. It is impossible here to deal with the measures adopted

in every district or to discuss the whole question. Voluminous papers are available as to the action taken and the extracts given above serve to give an idea of what was done. The total sum spent in rewards by the Bombay Government amounted to a little over two lakhs. As stated previously, this money was not only used to destroy locusts and prevent a fresh attack, but *was a form of State relief paid to those who suffered from the presence of locusts.*

In all some 1,500 millions were probably accounted for, including adults, eggs and hoppers: of these 66 millions were adults which would have laid eggs and would have been responsible for another 3,000 million hoppers had they lived.

Allowing for all chances, for weather (which was suitable on the whole in Bombay, though not elsewhere), enemies, birds, &c., there can be no doubt that the money was very well spent, in averting the occurrence of another serious locust year.

GOA.

The following report is extracted from the information published by the Government of Bombay:—

Letter to His Excellency the Governor-General of Portuguese India, No. 6568, *dated* 25*th October* 1904:—

"As information has been received by me that locust hoppers have made their appearance in Goa, I have the honour to address Your Excellency on the subject, and to suggest that should inquiry prove that the report is true, measures may be adopted for their destruction similar to those that are in progress in British territory.

"2. The accompanying Resolutions that I have the honour to forward describe the life history of locusts and hoppers and the methods employed for their destruction. Officers of all Departments have been directed to place their subordinates under the orders of Collectors for supervising the operations. Rewards have been offered for locusts and hoppers destroyed at rates varying from eight annas to one rupee per seer, the rates being fixed so as to give the labourers employed a sufficient daily wage. Finally, proclamations have been issued warning rayats who fail to co-operate in the work that they will not receive remissions on land revenue on account of damage that may be done to their crops by locusts. The result of the operations is that several hundreds of

Government Resolution	No.	2912,	dated 16th April 1904.
"	"	3843,	" 21st May 1904.
"	"	5023,	" 1st July 1904.
"	"	5182,	" 7th July 1904.
"	"	5297,	" 12th July 1904.
"	"	5587,	" 21st July 1904.
"	"	6176,	" 13th August 1904.
"	"	6433,	" 22nd August 1904.
"	"	6765,	" 5th September 1904.

maunds of hoppers have been destroyed in this Presidency, and the numbers now to be seen are reported to have sensibly diminished.

"3. I beg to point out the danger to Portuguese as well as to British territory that will result if the locusts are not reduced in numbers by systematic and organized measures while they are still in the hopper stage."

Letter from His Excellency the Governor-General of Portuguese India, No. 100, *dated* 11*th November* 1904 :—

"I have the honour to acknowledge with thanks Your Excellency's letter No. 6568, dated the 25th ultimo, with copies of Resolutions regarding locusts.

"This Government have also taken some measures in the matter under the Notification No. 34, dated 3rd February last, a copy of which herewith enclosed, giving some instructions to the chief authorities of the district for the strict fulfilment of the provisions to be adopted, and to take energetic measures with the view of destroying the locusts wherever they make their appearance.

"A copy is also forwarded herewith of the report regarding the last invasion of acridiæ, which was forwarded to His Britannic Majesty's Consul at Mormugao, who had asked for it in order to comply with the request of Mr. W. S. Owen on special duty regarding locusts in the District of Kánara. In that report, as result of the observations made, it has been found that the insects do not lay eggs in Goa. However, it is certain that among the acridiæ, which about a week ago have made their appearance in several places of this territory, some young hoppers are seen, which fact leads to the supposition that some eggs were laid here though it has not been possible to verify positively."

NOTES ON THE LATEST INVASION OF THE PORTUGUESE TERRITORY OF GOA BY LOCUST.

I

History of the invasion.

Principal characteristics of the invasion.

1. The invasion of the Portuguese territory of Goa by locusts is chiefly characterised by the *non-permanence* of those insects in this territory; swarms more or less numerous crossed into Goa, generally not staying more than two months, disappearing completely, and re-appearing some time after in the same year.

Epochs of the partial invasions in a year.

2. Considering the period of one year, the first invasion takes place after the copious rains of the south-west monsoon, *i.e.*, during the months of September, October and November; in January or in the beginning of February fresh invasion takes place, which generally lasts till the end of March, and another invasion,

weakest of all, takes place in May. During the rainy season, between June and the middle of September, locusts have not been seen in Goa.

The intermittent invasions considered as a single invasion.

3. Although the invasion is characterised by the non-permanence of the locusts in our territory, it should be considered as a single invasion which lasted during the months referred to in paragraph 2 from September 1901 to May 1904.

Annual invasions' history.

4. For purposes of the history of the annual invasions the month of September should be taken as the starting point. In September 1901 locusts were seen in large swarms in the District of Satary destroying the hill crops to a great extent; they stayed in the hilly ground at the foot of ghâts, only an insignificant portion descending south and advancing westward; they remained there a short time and returned to British territory. It may be said that during the remainder of 1901 and a part of 1902 up to September the locust plague did not re-appear.

History of the invasion of 1902-3.

5. In September 1902 a similar invasion took place chiefly in Satary, but extending also towards the east of the Portuguese territory, being notorious on account of the swarms that swept down to the lowlands, causing terrible damage to the cocoanut and betel-nut plantations and also to the mango plantations and rice crops (vangana) which were ready for harvesting. This invasion of our territory lasted till the beginning of April 1903. The same year there was a fresh invasion in May, but in insignificant numbers. The migrations of 1902-03 as a whole cannot be classified as a public calamity; the damage to the crops was considerable, but it was not much felt except by such of the inhabitants of Goa as at the foot of the ghâts exclusively subsist on hill crops.

History of the invasion of 1903-4.

6. The invasion of 1903-4 from the very first was of exceptional violence. In September 1903 it localised at Satary and Embarbacem; it completely destroyed the crops on the high ground cultivated during the rains; and further strengthened by fresh arrivals of enormous numbers of acridiæ from the neighbouring territory, it extended to the lowlands of the said provinces and of Pernem and Sanguem, devastating the cocoanut and betel-nut plantations and but slightly damaging the rice crops which had been to a great extent already harvested.

About the end of December 1903 the locusts disappeared suddenly and completely from the Goa territory, when it was very much feared they would wend their way towards the more intensely cultivated portions along the sea-board. There is no plausible reason for the disappearance. The prevailing wind was north-easterly which should have rather helped them on. The only cause that might account for the sudden retreat of the insects is the rapid fall of temperature and the consequent increase of dews in the locust-infested area. About the end of January 1904 the invasion was repeated, increasing with extraordinary violence hitherto not heard of in this part of the country during the first

half of February. Clouds over clouds of locusts of great length, breadth and thickness flew in all directions over our territory, having entered it from the north-east and from various points on the eastern frontiers. During the passage they destroyed cocoanut, cashew, mango and betel-nut trees, injuring also almost all other trees, but luckily sparing the rice crops (vangana) sown in flooded fields. The heavy columns of locusts generally entered the Portuguese territory through the passes in the ghâts, and after making good their footing here, although extending over vast regions, it was found they had a tendency to move westward, sometimes flying very high and at others close to the ground, generally along the valleys avoiding the wind which had then commenced to blow from the sea. Early in February the nights being moonlit, the locusts did not rest, but proceeded on their onward course availing themselves of the hill, so that cocoanut plantations that were in splendid condition overnight were completely denuded of their leaves by the following morning. It was these nocturnal devastating raids that struck terror into the inhabitants of Goa. The raids which were recommenced and continued during the whole months of February and March and early part of April 1904 with more or less intensity, became a public calamity in consequence of a great destruction of the cocoanut, betel-nut and cashew plantations of Satary, Embarbacem, Panda, Astragar, Sanguelim, Parnem and Canacona and although they extended further west they did not cause grievous damage in the *Velhas Conquistos*. In the first fortnight of April 1904 the locusts vanished away from the Goa territory, but they returned in smaller numbers in the course of the month of May, vanishing again altogether before the commencement of monsoon, from which date they have not turned up.

History of the invasions as a whole from 1901 to 1904.

7. The locust invasion as a whole from September 1901 to May 1904, besides the peculiarity of non-permanence noticed in paragraph 1, presents two other points worth mentioning:—

The increase in violence and intensity successively on a rising scale; the ever forward movement of the locusts towards tracts more distant from the ghâts into more intensely cultivated regions near the sea-board.

By this time, with reference to these two points the invasion attained its maximum in the month of February 1904. On no previous occasion were the clouds of locusts so numerous and dense or had they so much approached the sea, penetrating into many a kilometer of Bardez district and reaching the western portion of the districts of Ilhas.

Probable causes of the non-permanence of locusts in Goa.

8. The non-permanence of the locusts in the Portuguese territory of Goa with regard to their retreat in November and December might be accounted for by the great fall of temperature in those months at night at the foot of the ghâts and the heavy dews almost akin to rain which soaked the soil between sunset and sunrise. It must be admitted that this explanation does not show the reason why instead of retreating eastward they did not move westward where the night temperature is equal to the day temperature with

a slight difference, where there is no dew and where there is no lack of things to feed on, besides the north-easterly wind would have helped them to go westward.

As to the retreats about the end of March or beginning of April, they should be ascribed to the strong winds which about this time begin to blow from the sea ; this also accounts for their not having been able to penetrate into tracts nearer the seaside in spite of the repeated attempts made this year.

II.

Breeding soil of locusts.

Egg-laying and hatching.

9. The very fact of the non-permanence of locusts in the Portuguese territory of Goa (the annual invasions being composed of three partial ones, of which the most persistent lasts but two months) leads to the conclusion that the insects do not lay eggs at Goa.

Observations support this conclusion, for no young locusts in larval and unfledged stage have been found in Goa, except in very insignificant numbers, neither batches of eggs. But all the same, bearing in mind the virulence of the invasion of this year, the necessary investigations have been instituted to find out whether locusts are being hatched in this country and to what extent.

III.

Points and direction of the locust invasion of the Portuguese territory.

Points of invasions of Portuguese territory.

10. The locust invasions have generally penetrated the Portuguese territory of Goa through the north-east angle, Satary being the first place to suffer. The locusts appear to come from Kolhàpur and Belgaum into our territory, entering it at Satary and spreading thence over the rest of the country. But when the invasions become very dense, the points of ingress are more numerous and extend over the eastern frontier line and southern limit of Goa, the locusts advancing protected as much as possible from the prevailing winds.

IV.

Preventive measures taken against the locusts invasion.

Steps taken against the invasions.

11. All the measures devised against the locusts are mentioned in the Government Notification No. 34* of the 3rd February of this year, which accompanies these notes.

Published as it was while the enormous invasion by acridiæ was at its highest stage, there was some hesitation in the execution of some of these measures, so that it was not possible to appreciate the results that might have been expected. At any rate the following conclusions appear reliable :—

(*a*) When the invasion is intense and violent, as in February this year, hardly any results may be expected.

(*b*) When the invasions are less violent, the adoption of the measures indicated in paragraph 8 of the instructions that accompany the Notification

* Not printed.

No. 34*, such as rattling of tin pots, burning fireworks, &c., gives results, because in this manner it has been often possible to drive away the locusts into uncultivated areas, and to prevent their entering more intensely the cultivated lands. Even during the great invasion of February the enormous columns of locusts were by these means prevented from entering the districts of Salsete and Bardez.

(*c*) The emulsion of soap and petroleum gave no results at all.

(*d*) Fires hardly gave any result.

(*e*) Bagging or catching the insects always gave good results; they are immediate when the invasion is not great, and futile when the invasion is exceptionally severe.

It would be advisable if the British Government had made bagging compulsory in the invaded areas. The study of the means of destruction of the acridiæ and their application, although they may not appear to produce great success, yet it is the duty of all Governments.

The fact that bagging does not produce immediate results causes it to be considered useless, regardless of the circumstances that the invasions have to be reckoned with for a series of years, and that the apparently insignificant results therefore, enhanced by the destruction of female locusts.

Catching can be carried out with comparative facility, and good results in Goa, at nights and before daybreak, when the locusts are in a torpid condition owing to dampness and dews. During the day it is far more difficult, but gives good results in certain kinds of lands.

The Notification No. 34 prescribes *compulsory free* labour for the destruction of locusts, of 48 hours per year on consecutive days or otherwise for each man of the invaded region between 15 and 50 years of age; *compulsory paid* labour, besides free labour, being compelled to produce 4 curos of locusts payable at the rate of one anna and six pies per curo; *voluntary remunerated* labour at the rate of one anna and six pies per curo brought in.

It is believed that if unfortunately there should be new invasion, as it is feared, then the labour of these working hands, being properly organised and supervised, must produce satisfactory results.

V.

Final remarks.

Damages. necessity of warning of the approach and of measures adopted for destruction.

12. The damages caused in the current year by locusts in Goa territory were very great, but not to such extent as the farmers would make it believe. But the damages will be enormous if the locusts succeed in invading the sea-board regions and destroying the leaves of the numerous magnificent paying cocoanut trees, which are one of the principal sources of the revenue of the country. This is a cause of constant

*Not printed.

anxiety to us, and it would be well if the Governments of British India would warn us of the approach of the locusts of our territory, and of the kind of aspect which the invasion bears, informing us also what measures have been adopted for the destruction of locusts and results obtained.

(Signed) T. M. PEIXOTO VIEIRA,

GOVERNMENT SECRETARIAT, *Chief Secretary.*
6th August 1904.

KOLHAPUR.

The following is extracted from the information published by Government of Bombay:—

Copy of letter No. 102, *dated the* 19*th March* 1905, *from the Chief Revenue Officer, Kolhápur, to the Diván of Kolhápur.*

"With reference to your No. 3827, dated 17th November last, asking me to report as to what measures have been adopted for the destruction of eggs, hoppers and adult locusts and with what measure of success in this Principality, I have the honour to state as follows:—

"It may be generally observed at the outset that the Darbár has throughout assimilated its measures in this matter to those of the British Districts. In my letter No. 207, dated 21st June last, I have already stated in detail how a working establishment was organised to carry out the measures adopted, and communicated to the Darbár, from time to time, by the British authorities, and have also furnished in weekly reports, &c., information regarding the movements and destruction of the hoppers, &c., in this Principality. It would, therefore, be unnecessary to repeat the details again, and the following summary in brief of the measures in question would, I think, suffice for the present purpose.

"First, it is gratifying too bserve that though swarms of locusts were seen all over the Principality in the months of April, May and early June, they did not settle permanently anywhere except in some grasslands and hilly tracts in the Chanwad Mahál of the Panhala Petha; and almost all the area being free of crops, they did not cause any material damage. The people, therefore, would not readily offer their assistance in destroying these adult locusts, and so they could not be destroyed in any perceptible quantity. In the latter part of June and in July the winged flights were not heard of anywhere. In the beginning of August a report was received from the Chanwad Mahál about locusts in small numbers being seen in a state to lay eggs in the grasslands, &c. On receipt of this information the District Officer, N. D., and the State Forest Officer, to whom the management of the locust operation was chiefly entrusted, were at once deputed to the Ghât Districts to search for the eggs. But in spite of their arduous efforts they could not find any. Some eggs were seen in the ovipositors of killed female locusts. Shortly afterwards, however, the appearance of the young brood in some villages of the Mahál was reported to me, and in the middle of September the young hoppers were seen in some villages of the Panhala Petha. On receipt of these

reports circular orders were at once issued to the working establishment to commence the several operations with the help of the people to whom rewards were offered at the same rates as prevailed in the British Districts. In the beginning the young hoppers were so small that as many as 1,000 of them weighed in one tola, and would be found very difficult to destroy. Some 67 persons could not, with hard labour, destroy more than 102 tolas in one day. Young hoppers were also reported to have appeared in the vicinity of the Alta Hill, but on account of their small size they could not be identified with the Bombay locusts. A few of them were, therefore, sent in a tin to Mr. Tudor-Owen, who, after subjecting them to microscopic examination, informed me that they were mostly "long-headed rice grasshoppers." They being, however, destructive to rice crops, he strongly urged upon me the necessity of destroying them. Intructions were also received from the Director of Land Records and Agriculture for destroying all kinds of hoppers indiscriminately, and circular orders were issued accordingly. Generally the use of the bags attached to bámboo frames, suggested by H. Maxwell Lefroy, Esq., Entomologist to the Government of India, and communicated to me under your No. 2662, dated 3rd August last, was adopted, the materials required being supplied at the State expense. In some cases where the method was found inconvenient, simple bags with strings attached to the four corners at the opening without bámboo frames were rapidly dragged over young crops and the hoppers collected therein were destroyed by twisting the bags. In this way nearly 24 maunds in weight of hoppers were destroyed last year.

"The Kárbhári of Bávda reports that by adopting similar measures, for which he received instructions from time totime from me, some ten maunds and a half weight of hoppers was destroyed within the limits of the Feudatory estate."

Letter No. 101, *dated 20th January* 1905. *To the Political Agent, Kolhápur and Southern Marátha Country.*

SIR,

With reference to your No. 4605, dated 12th November last, forwarding copy of Government Resolution, Revenue Department, No. 8435, dated 1st idem, I have the honour to submit the following information furnished by the State authorities of all the States under my subcharge, regarding measures taken by them for the destruction of eggs, hoppers and adult locusts :—

Sángli State.—No eggs and hoppers were found in the State; some thin swarms of green locusts had made their appearance in October last in some villages of the State. But their stay was nowhere longer than four days, and they did not do any appreciable damage to crops. They could be caught by hand on foggy mornings when settled on the fields. About 206 lb. of locusts were destroyed in this way by the owners of the fields. At present all the villages in the State are free from locusts.

Miraj Senior State.—Many swarms of locusts had appeared in the villages of the State during the summer and also in the month of October. They stayed a very short time, and many died from cold during the first few days of

November. No eggs or hoppers were observed, and there are at present no locusts in the State.

Miraj Junior State.—Only one swarm of locusts appeared in October last, but it was thin, and did not do real harm, and consequently no measures were adopted for their destruction.

Kurundvád Senior State.—As no eggs were deposited within the limits of the States, no measures were needed for their destruction.

Kurundvád Junior State.—No eggs of locusts were found in any tálukas of the States except Yalur, where hoppers were destroyed by means of a bag mentioned in the brief note on locusts dated 13th April 1904. At present there are no locusts in the State.

Jamkhandi State.—Swarms of adult locusts had appeared in June last, and as their stay was very short and no appreciable damage was done to the crops, no special measures were taken for their destruction.

Mudhol State.—As neither hoppers nor adult locusts have reappeared since their last disappearance in summer, no measures were taken for their destruction.

Rámdurg State.—No eggs of locusts were found in the State, and consequently there arose no necessity for their destruction.

I have, &c.,

R. S. POTTINGER, *Captain,*
Assistant Political Agent, Kolhápur
and Southern Marátha Country.

APPENDIX B.

EXTRACT FROM A REPORT.

No. $\frac{3513}{1\text{-}126}$, *dated the 24th June*, 1905.

By B. P. STANDEN, Esq., I.C.S., C.I.E.,

Commissioner of Settlements and Agriculture, Central Provinces.

Arrival of the locusts and preliminary measures taken.—In October 1903, the arrival of locusts in small numbers was reported from the Chikhli and Malkapur taluqs of the Buldana District, and in November a similar report was received from Akola. Little or no damage was caused to crops and the locusts very soon disappeared. The pest, though active, I believe, in the Bombay Presidency throughout the cold and hot weather, left these Provinces unmolested until May 1904. On the 26th April the Bombay Government warned us that swarms of locusts were reported from the Deccan and Southern Maratha districts, travelling eastwards, which might invade these Provinces.

On the 20th May, the Deputy Commissioner of Buldana reported their appearance in the Chikhli taluq, and between this date and the middle of June the insects spread rapidly over the whole of Berar and the western districts of the Central Provinces. The tracts infested were, in addition to Berar, the districts of Nimar, Hoshangabad, Betul, Chhindwara, Wardha, Chanda, and the greater part of Nagpur, and throughout the period during which the pest was present these limits were never exceeded.

As soon as reports of a widespread invasion were received, Deputy Commissioners of the infested districts were instructed to send specimens of the insects to the Government

Entomologist, Mr. Lefroy. It was, of course, of the highest importance to ascertain whether the locusts had already laid eggs or were about to do so, for on this would depend the question whether the country was to suffer from a really serious plague of the insects. The full grown locusts which had arrived, though very numerous, were not banded in swarms, and the damage which they could do at a time when there were no crops on the ground was of comparatively slight importance. Mr. Lefroy reported that the specimens sent to him contained immature eggs, and that egg laying might be expected to begin soon. Instructions were issued to impress upon the people the gravity of the threatened plague, and a search for eggs was recommended. Meanwhile I asked all Deputy Commissioners to report the arrival of locusts in their districts, and suggested the appointment of special officers of the standing of Naib-Tahsildars to supervise operations, and the division of districts into circles supervised by capable Patwaris. It was important that measures for a campaign should be organised before the appearance of the young hoppers.

Towards the end of June the locusts began to couple, and soon afterwards egg laying began. Coupling and egg laying lasted about a month, and were over before the end of July. These functions mark the end of the locust's life, and the insects now rapidly died off. By the beginning of August they had practically vanished. The next development to await was the appearance of the young hoppers. Mr. Lefroy kindly offered to pay a flying visit to Berar and examine the situation there, and on the 16th July he met the Commissioner and myself at Amraoti. The question of making payments for the destruction of locusts was discussed, but it was decided not to attempt this, owing to the difficulty of measuring payments by results, and the risk of peculation which would be present if payment of money were entrusted to numerous subordinate officials. The best plan seemed to be the sub-division of districts into circles under officers who would explain the importance of the matter to the villagers, show them the best means of fighting the pest, and, as far as possible, see that they

availed themselves of these means. Mr. Lefroy explained several methods of destruction, which will be described later, and it was decided to explain these methods at a meeting of special officers to be held at Akola. This meeting was held on the 20th July, when I took the opportunity of explaining to the special officers who had been sent from all districts of Berar, and a number of native gentlemen invited by the Deputy Commissioner, the general plan of campaign, and of showing them samples of the mechanical contrivances recommended by Mr. Lefroy. The special officers were then sent back to their districts, and Deputy Commissioners of all the infested districts were recommended to place a special officer in charge of the operations in each tahsil or taluk, while Revenue and Circle Inspectors and selected Patwaris were to be put in charge of circles under the supervision of the special officers. Every effort was to be made to explain the gravity of the situation to the cultivators, and villagers were to be shown how to prepare apparatus for the destruction of the locusts. The special officers were to be of the standing of Naib-Tahsildars, new appointments being created, if necessary. Copies of a memorandum by Mr. Lefroy, in which various contrivances for hopper-killing were described, were sent to all districts except those from which special officers had come to the Akola conference. In addition to this, a note was drawn up in my office describing the life history of locusts and the developments of the pest which might be expected. This note was sent to all the affected districts, and translations in Hindi or Marathi were widely distributed and published in the *Agricultural Gazette.*

Methods and contrivances experimented with. (i) *The American "hopper dozer."*—This is a bag on a sledge. On the sledge-runners a bag is erected in such a way that it will stand up well when the sledge is running, and can be easily and quickly collapsed when the haul of hoppers is to be destroyed. The bag has a wide open mouth facing in the direction in which the sledge travels, into which the hoppers jump when the machine is about to overrun them. This contrivance was found to be

heavy, expensive, and not very efficacious ; it cannot be used in crops or on rough ground, and may be said to have been a failure. No further description of it is therefore necessary.

(ii) *The Russian wheeled revolving brush.*—The principle of this contrivance is similar to that of the revolving brush used for sweeping mud from streets, except that the axis of the brush is at right angles to the direction in which the machine is travelling instead of being placed obliquely. The machine consists of two wheels and an axle which revolves with them. Thorny bushes are attached to the axle which has holes prepared to receive their stems. A bag is fastened behind the machine, and as the axle revolves the locusts are brushed up into the open mouth of the bag. This was found fairly successful, but the machine is expensive and the fixing of the bag in such a way as not to interfere with the rotation of the axle and wheels requires no little ingenuity. Cheaper and more effective contrivances were devised, and this machine is therefore not recommended.

(iii) *The capacious bag.*—This is made of cheap country cloth and resembles a huge bolster-case about ten feet in length by six in breadth, with one of the long sides open. Two men take each one of the corners at the end of the open side and drag the bag rapidly over crops. The locusts fall into the bag, which can then be twisted up and the insects crushed. This was found effective and has the advantage of cheapness.

(iv) *The bag and frame.*—This contrivance was suggested by Mr. Lefroy, and proved very successful. A light bamboo frame is prepared and placed inside a bag, one side of which is open and kept open by the frame. Cords are attached to the frame and it is drawn rapidly over the ground. Hoppers get into the bag, which is periodically taken off the frame and the hoppers are crushed. This contrivance is very light and can be easily worked by one man. When it is to be drawn over crops the frame can be taken out, and the mouth of the bag be kept open by two bamboos. The absence of the frame obviates all risk of damage to crops. This contrivance

was most successful so long as the crops were young and of small height. A full description of it was given in a leaflet which was translated into Hindi and Marathi and widely distributed.

(v) *Poison.*—All poisons are very dangerous owing to the risk of the poisoned grass or other substance being eaten by cattle. Mr. Lefroy, however, recommended a preparation composed as follows :—

Lead arseniate	...	1 lb.
Jaggery ...	...	5 lb.
Water ...	...	100 gallons.

This mixture may be sprayed upon fodder, or fodder may be dipped into it without harming cattle. It is said to kill locusts. A great objection to the use of poisonous mixtures is the difficulty of finding out to what extent the locusts have been destroyed, since the dead insects are at once carried off by birds, ants, etc. The lead arseniate mixture was tried in Nagpur, but was received too late to be given a fair trial. It failed completely in Wardha.

(vi) *Beating with brooms and branches.*—This is the simplest and most effective way of dealing with the locusts before they have developed wings. Winged locusts can also be destroyed by this method with the utmost ease when in the act of coupling, as they then make no attempt to escape, and a single blow from a broom or branch will destroy the pair. It is, of course, of the highest importance to destroy the locusts at this stage, as the destruction of each female prevents the laying of a hundred eggs or more. In places where the people were willing to destroy the locusts they took readily to this method and children were frequently thus employed.

(vii) *The borax and tamarind mixture.*—A mixture of borax and powdered tamarind leaves was tried as a means of poisoning the insects. It failed almost entirely.

(viii) *Bonfires.*—Bonfires were lighted at night in order to lure the locusts to self-destruction. A few are said to have been thus destroyed in Basim after the insects had begun to swarm, but elsewhere the experiment was a failure.

(ix) *Kerosene oil.*—Kerosene was tried in all districts, and the Nimar report contains an interesting account of the experiments made and an estimate of their results. I quote from the report :—

"Kerosene oil was used in several places for the sake of experiment. Half kerosene oil and half water was sprinkled in fields abounding in very young hoppers and it was observed that they died immediately. The experiment was repeated in three or four places and was found successful. But it failed where the hoppers had changed colour and had grown to an inch in size. Only pure kerosene oil could cause their death. The method was costly and could not be pressed on the people. Besides, it was reported from one or two places that the crops standing in places where oil had been sprinkled had withered. This however, was due to want of moisture in the fields. In a paddy field at Palsud, where hoppers swarmed in large numbers, kerosene oil was sprinkled, and the area was marked with a view to seeing its effect. There was rain in the evening and on the days following, and no injurious effect was produced on the crop. Some people said they had made the same experiment last year, but without any success. But they said no injury was done to their crops. The reason why their experiment failed was that they tried it when locusts were full grown. Fully-grown locusts do not die unless they are actually steeped in the oil. The bigger the insect the greater is the quantity and strength of the oil required.

Kerosene oil can be used with advantage where the crops are high, and where bags and cloths are of no avail. Iron or brass pans are placed at several places in a field teeming with hoppers, and the hoppers are driven with branches towards these pans from all sides. When pressed from all sides they jump into the pans and die in a short time. When the pans are full the hoppers are taken out and thrown away. The oil is left for further use. This method does not cost much, but is laborious. It is to be employed as a last resort in fields where, owing to the height of the crops, other methods cannot be employed.

One method does not succeed everywhere. The methods must be changed or modified according to circumstances."

Development of the pest and the campaign against it.—Hoppers appeared in the first week of August, and hatching was general almost throughout the month. As soon as it appeared in each district that the insects were present in sufficient numbers to warrant active measures being taken against them, the supervising agency was brought into existence and set to work. The organisation in the different districts was generally on the same lines, a specially appointed Naib-Tahsildar being placed in general charge of the operations in each tahsil. Villages were grouped in batches of 25 or 30, and these groups were placed in charge of selected Patwaris, or in Berar, of Patels. Revenue and Circle Inspectors were employed in supervising the work of the group officers, and the duty of all the supervising officials was to tour constantly in their charges, show the people the best way of fighting the pest, and to induce them to take measures of self-defence. Paid labour was not employed by Government except to a limited extent in Betul, Ellichpur and Akola. In Akola Rs. 130 and in Ellichpur Rs. 250 were spent in Government forest areas. Many Malguzars, Patels, and wealthy cultivators, however, organised and paid for labour. In Hoshangabad as much as Rs. 9,290 is said to have been privately spent in this way. In Wardha some members of Local Boards showed a keen interest in the campaign, and rendered most useful assistance. Samples of bags and other contrivances were shown to villagers, and they were encouraged to make them for themselves.

Under instructions from the Secretariat a weekly report on the locust visitation was sent by me for the information of the Chief Commissioner, and to enable me to do this the Deputy Commissioners of the infested districts sent me similar weekly reports on the subject.

An Entomological Assistant of the Agricultural Department was instructed to tour in Berar, and gave some well-attended demonstrations of the best methods of hopper-killing.

All the methods of destruction mentioned above were tried, and the cheaper ones were almost universally found to be the

most efficacious. At the end of August the migratory juari bird ("rosy pastor," vernacular *bhordi*), which generally appears just before juari comes into ear, arrived. Owing to the unwonted earliness of its arrival, and the fact that its plumage, which changes as the season advances, had not yet taken the colour familiar to the people, there was at first some uncertainty as to its identity with the well-known annual visitor. Little was heard of it in September, and even as late as the beginning of October it was mentioned in a Chhindwara report as "a new bird from the south." It now seems to be generally agreed that it was the familiar juari bird. In October these birds rendered remarkable assistance in clearing off the pest. Large flocks of them appeared, and in some places made a clean sweep of the insects, which by this time had left their grassy breeding places, and were attacking the juari crop. Other birds which readily devoured locusts were minas, kites and crows. Even foxes, cats and dogs are said to have eaten them occasionally.

The crops which were most generally attacked were juar, tur, mung, rice, and the lesser millets. Tur suffered most, but easily recovered after rain. Rice was seriously damaged in parts of Betul, where its cultivation is confined to small low-lying patches of land. The crop is greedily attacked by locusts, and it is fortunate that it is a comparatively insignificant crop in most of the tracts which were infested. The invasion, in fact, just stopped short of the true rice country. On the other hand cotton, which greatly predominates in nearly all the tracts invaded, seems to possess little or no attraction for locusts, and escaped almost untouched. Juar was readily attacked, the leaves in some fields being thoroughly riddled and remaining like mere skeletons of themselves.

The young ears of juar and also of rice were attacked so long as the grain was in the "milky" or soft stage. The very young hopper seems to like grass as much as any other food, and it was only when the insects grew to about an inch in size that they attacked the crops in large numbers. Owing to this habit of clinging to their hatching grounds, the measures taken

against them and the valuable aid given by birds and other natural enemies of the locusts, the extent of the damage was nowhere serious, and no necessity of rental or revenue remissions arose, nor do the people seem to have expected anything of the kind. I am inclined to think that an estimate of two annas damage in the rupee over the whole area affected is beyond the mark, and in some places no damage whatever was caused. A remarkable feature of the life history of the Bombay locust—and here it differs entirely from the marching locust of Cyprus and other places—is its unwillingness to leave the place of its birth until its wings have grown and it is capable of flying. In many villages some fields might be found in which the crop was damaged by hoppers to a really serious extent, in some cases being even left unharvested, while in other fields of the same village similar crops would escape quite untouched. The only reason for this must be that the fields invaded adjoined the places where eggs had been laid, and the hoppers hatched.

The season is believed to have been favourable to the pest. The monsoon rainfall was considerably below the average, and bursts of rain were followed by long breaks. There is much diversity of opinion on the effects of rain on locusts. It is generally agreed that after the hoppers have passed beyond the early and helpless stage, rain causes them little, if any, harm. But as regards its effect on very young hoppers opinions differ. In Wun hoppers were found dead after heavy rain, and in September parts of the Melghat were said to have been completely cleared of hoppers from the same cause. On the other hand, many officers think that rain has no effect on the insects. Nothing, then, has been proved. Young hoppers would probably be washed away and drowned by a flood.

In Betul locusts nearly fully grown were found dead and infested with a tiny red parasite. This parasite was also found in Wardha. The Entomological Assistant found it present in Nimar, but could not discover that it caused any harm to the locusts. They were, however, killed by a kind of grub, which subsequently developed into a fly not unlike the common

house-fly. Specimens were sent to the Entomologist to the Government of India, but I have not heard whether they have been identified.

In the middle of September, under instructions of the Director of Public Instruction, all rural schools in the affected districts were closed, in order to enable the schoolboys and their masters to learn the methods of locust destruction, and themselves aid in the work. This order was received with some dissatisfaction by parents of boys of the better castes, and it required strong personal influence on the part of the Master and Malguzar or Patel to give proper effect to the scheme. In many places, however, the boys were most useful and willing helpers. The schools remained closed for about six weeks.

As the cold weather approached, the method of catching locusts by hand, when they are torpid and benumbed, was successfully practised, but cultivators were generally too busy with rabi sowings to give much further help.

Before the end of October the locusts began to manifest the swarming instinct, and in the beginning of November migratory movements were noticed. These movements were generally in a westerly direction, and continued throughout November. By the beginning of December locusts had entirely disappeared and with them vanished all fear of damage to the valuable rabi crops, which had just germinated.

Attitude of the people.—Except in Nimar, where locusts have done some damage of recent years, it was at first very difficult to awaken the people to a sense of the calamity with which they were threatened, and even when the young hoppers appeared in large numbers they were believed to be ordinary grasshoppers, such as often appear in places during the rains. There was a universal belief that the locusts were a manifestation of the power of God and a sign of the divine wrath against the sins of men. Sadhus and fakirs, of course, took care to foster this belief. Recourse was therefore had to various forms of worship and incantation. The most common practice was to make images of the insects in clay, or even gold, and then worship these. Often a few locusts would be caught alive, and

after food had been placed before them they were worshipped and begged to go away. A common vernacular term for the locust is *ghoda* (horse), and there was a widespread belief that the insects were the horses of the god Mahadeo sent to ravage the land as a sign of his wrath. A curious belief was current in the Satpura districts of Betul and Chhindwara. The god Mahadeo lives in the Pachmarhi hills, and an estate near Pachmarhi has been taken under the management of the Court of Wards. Mahadeo has not received proper worship—so ran the story in Chhindwara—since the estate has been thus assumed, and showed his anger by sending the locusts. In Betul the story took a slighty different form. There, it was believed, that the estate has a ravine which is a sort of locust preserve, and that the locusts, not being properly looked after and fed under the Court of Wards, emerged and ravaged the surrounding country. The belief in a place as a stronghold of locusts has its counterpart in Chhindwara, where a hill named "Tiddi kot" or "Tiddi ghar" in the Almod Jagir is believed to be the home and breeding place of the insects. Enquiry and inspection, however, showed that the locusts were no more numerous there than elsewhere. Another common belief was that for each locust destroyed two would appear, and this belief, as the Deputy Commissioner of Betul points out, is not so unreasonable as it seems, for as the young hoppers grow in size they leave the patches of grass in which they are hatched and invade the crops, thus apparently increasing in numbers in spite of all efforts to destroy them. In some of the Maratha districts it was believed that the sprinkling of water taken from sacred tanks and other holy places would have the effect of banishing the pest.

As the young hoppers grew in size and it became apparent that they were damaging the crops, the apathetic, not to say antagonistic, attitude of the people was to some extent broken down. It was seen that Government was in earnest in its efforts, and some credit was even given to Government for having foreseen that hoppers would appear after the old locusts, which appeared in June, had disappeared, and for taking steps to warn the people in time. In the Sulgaon Circle of Nimar the

people took readily to the work of destruction, having seen their crops damaged by locusts in the previous year. Generally speaking, the people were more amenable to reason in the Maratha districts than elsewhere, and in Wardha they are said to have displayed so much keenness in the campaign that in some villages lists of cultivators were framed and the number of locusts destroyed by each was daily noted against his name. Good work was also done by villagers in Basim, Buldana and parts of Chanda. As might be expected, the higher castes like Brahmans, Jains, etc., were most averse to the work of destruction, but even the higher castes were ready to employ hired labour for the work as soon as the menace to the crops was felt to be a real one. Low castes like Mahars, Gonds and Korkus showed little reluctance, and in some places exerted themselves strenuously. When the village schools were closed in order to allow of the help of the schoolboys being utilised, many of the parents among the higher castes were strongly opposed to their children being employed in the work of killing locusts, but the boys themslves took gladly to their new occupation and derived a good deal of amusement from the work. In many cases village schoolmasters rendered most useful help. The extent to which the people were willing to co-operate everywhere depended largely on the energy and influence of the supervising officials, and should there be another locust invasion in the near future, it is hardly likely that so much initial opposition will have to be overcome again.

Estimate of the success of the operations.—It is, of course, impossible to form any but the roughest estimate of the degree to which the pest was diminished by the operations taken against it. The Deputy Commissioner of Wardha considers that a third of the total number of hoppers was thus destroyed, while some malguzars in his district estimate the proportion as a half. From what I saw in the neighbourhood of Hinganghat I have little doubt that the efforts of the villagers had an appreciable effect on the numbers of the insects. Our efforts were aided in remarkable fashion by juari birds ("rosy pastor"), which arrived in large flocks earlier than usual, and devoured

the locusts greedily. They arrived just at the time when the young hoppers had grown large enough to be active and formidable, and it is believed that enormous numbers of the insects were destroyed by them. It is possible that the preservation of the crops was due as much to these birds as to the efforts of human agency. Lastly, the pest suddenly disappeared when it had become impossible to take effective measures against it. As soon as the locusts were fully grown and had developed the power of flight, they entirely vanished in the course of a few days, migrating, it is supposed, to the ghâts of Bombay, where the Deccan locust is believed to have its home.

APPENDIX C.

REPORT BY THE DEWAN, RAJPIPLA STATE, ON THE LOCUST INVASION OF 1904.

THE first appearance of locusts in the State during the year was on the 18th of April. It was in the Dediapada Taluka, which forms the Eastern part of the State. They probably came from the Khandeish Mehwas territory lying to the East of the said Taluka.

2. A second flight of locusts passed over a portion of the Gardeshwar Taluka, which forms the North-Eastern corner of the State, on the 19th May. This swarm is also believed to have come from the East; in the present instance, from the Kanti Estate of the Khandeish Mehwas.

3. Locusts had appeared during the previous year also (in October 1903) in the same localities and had spread from there to some villages in the West. They did some damage, but the only remedy tried was the ploughing up of bits of land in which locusts had remained and where it was possible they might have laid eggs. Owing, however, to uncertainty in this respect, and to the vastness of the areas involved, it was not possible to do much in this direction, and the results achieved were inappreciable, although a serious attempt was made wherever possible to plough up lands suspected to contain eggs. Not many eggs would appear to have been laid, however, and the locusts themselves either passed on or perished after doing some local damage.

4. The two flights of locusts, referred to in paras. 1 and 2 above, which appeared in 1904, were duly reported to Mr. Maxwell-Lefroy, Entomologist to the Government of India,

whose headquarters—luckily for this part of the country—had at that time been established in Surat, and specimens were sent to him in accordance with orders issued by Government on the subject. The fact that these flights did not pass away, as was at first hoped they would do, but lingered over different parts in the North and the East of the State, gave rise to serious apprehensions. The methods, originally recommended, of destroying locusts (screens, oilcloth strips, etc.), were not such as would at all answer in a tract of country like this, and it must also be admitted that the proper working of these was not correctly understood and the said methods did not, therefore, appear quite feasible. (The only methods which we did understand and attempted to put in practice were (1) that, already referred to, of ploughing up lands in which eggs were suspected to have been laid, and (2) trying to kill as many locusts as possible by means of long bamboos with brushes of palm or khakhra leaves, etc., attached to one end.) An application was, therefore, made to Mr. Lefroy for information as to whether there was any district in which the methods above referred to (screens, oilcloth strips, etc.), or any others, were being practically put to the test with even a moderate amount of success, in order that arrangements might be made for sending an intelligent official to that district with a view to his gaining a practical insight into the details of the operations in progress there. There appeared, however, no place where such measures were being successfully undertaken.

5. Mr. Lefroy was, however, good enough to furnish us with most valuable information, from which we, for the first time, learnt many important facts. For instance, the experience gathered from the appearance, at very rare intervals, of huge flights of the Central Asian locusts (the *Acridium peregrinum*) had taught people here that these foreign locusts flourished most in dry weather and that eggs would be hatched only in dry sandy places, while rain would prove destructive to locusts and to eggs alike. From the information which Mr. Lefroy was good enough to furnish most freely to

us, we learnt that far from proving destructive to locusts or eggs, rain would help, was in fact necessary for the propagation of the pest, that eggs were laid only in soil soaked with water to a depth of two inches or more, and that dry soil was not suitable for egg laying. We found that the locusts we had to deal with (the *Acridium succinctum*) were, although perfect foreigners here like the Central Asian locust, the *Acridium peregrinum*, an altogether different variety from the latter, and that they flourished only under the above conditions. The information thus obtained through the kindness of the Government Entomologist was of great value in helping us to a correct knowledge of places where eggs were likely to be found and where hoppers would very likely appear. We also learnt from Mr. Lefroy the probable period of incubation. It thus became very much easier than it had ever been before, to search for, and destroy, locusts' eggs and to be prepared for the appearance of hoppers with a view to their being destroyed before they were able to fly. I beg to append translation of a Circular Order (No. 2, dated the 8th July 1904) issued with the above object, marked Appendix A. Rewards were given at the rate of three annas per lb. of locusts and one rupee per lb. of eggs.

6. Soon afterwards, Mr. Lefroy was good enough to favour us with a visit, when he saw some of the villages in the vicinity of Nandod where locusts had been, and favoured us with further very valuable information and suggestions. Further orders for the destruction of eggs and of hoppers—as soon as they should appear—were issued and were carried out by the Taluka and Village Officials to the best of their ability.

7. On the 23rd of July 1904 Mr. Lefroy issued a pamphlet describing a simple and effectual method for the destruction of hoppers by means of a bamboo frame having a bag attached to it. He was so kind as to favour me with a few copies of this pamphlet as soon as it was out. The method described was perfectly intelligible, and a frame and bag were prepared at once in accordance with the directions and trials made with it. The results went beyond our expectations as will be seen

from the following extract from a letter addressed to Mr. Lefroy on the subject:—

"In continuation of the concluding portion of para. 2 of my letter No. 99 of the 27th instant, I have the honour to state that as soon as the first bag and frame were ready an experiment was made at a village about three miles from Nandod in a field near which locusts had been seen coupling. The field was about five acres in extent and was all grown over with grass which is, of course, as yet but small. The result of an hour's work in the field, under the personal supervision of the Suba, was the collection, in the bag, of a quantity of grasshoppers, locusts, and hoppers of various kinds which I do not find it possible to determine. I beg to send the whole lot by parcel and to say that the quantity is small *because the number of these insects in the field was small.* Otherwise, the experiment has clearly shown that the frame and bag work very nicely and effectually, that any number of hoppers that there might be in grass-land, or a grass border, or any other land, where the frame and bag could be used without fear of injury to crops, would be certain to be caught and that once inside the bag, escape would be impossible."

8. The cost of the first bag and frame made here was Rs. 5. Six more were made and sent out to each of the Talukas with detailed instructions embodied in a Circular (No. 9, dated the 1st August 1904), a translation of which is appended hereto as Appendix B. Three more were subsequently sent out to one of the Talukas (Dediapada) where need for action on a larger scale was felt more than in the other Talukas. These ten bags and frames, made at State expense, were for general use and for concerted action under official supervision, and instructions were given for others being made by individual cultivators the cost to whom would, it was pointed out, be much less than to the State. Everywhere the arrangement—worked as directed in Appendix B—proved thoroughly successful. Where crops were likely to be injured by the frame, the bag was used with two pieces of bamboo in

the place of the frame, in accordance with instructions given by Mr. Lefroy, and the experiment answered perfectly.

9. It fortunately so happened that a great proportion of the eggs laid were spoiled by some disease, or perhaps by reason of the prolonged drought, and did not hatch. A large proportion did produce hoppers, however, but many of these were destroyed by birds. (This had been the case with the grown-up locusts also even before the egg-laying period. It was remarked that the birds came after the locusts in unusually large numbers, and rendered great service in destroying the locusts, as they did, at a later stage, in destroying the hoppers). Large numbers of hoppers remained, however, and for ridding us of these, Mr. Lefroy's bag and frame arrangement was of the greatest value. The results, wherever it was used, were of the description noted in the concluding part of the quotation in para. 7 above.

10. In one village of the Valia Taluka, hoppers and locusts appeared as late as the end of September. They were confined, however, to a few fields situated close to some ravines of a description peculiarly favourable to the laying and hatching of locusts' eggs. It is worthy of notice that these fields were under fully grown Juvar crop. Mr. Lefroy's method was tried in these fields, however, with complete success, 26 lb. of hoppers and locusts (all that there were in the said fields) being destroyed in the course of a day or two ; and, as far as can be ascertained, there are now no locusts or hoppers anywhere in the State.

11. The huge flights of the Central Asian locust (the *Acridium peregrinum*) which, formerly passed over these parts, at rare intervals, struck terror into the hearts of the people. The damage done by them was immense. But it was localized, being restricted to the tract they passed over, and nothing more. The locusts passed away, generally the morning after they arrived, and the damage doing was confined to the day or two of their halt. The swarms of the *Acridium succinctum* which have been visiting these parts during recent years, though perhaps, less terrifying in aspect, do more real damage, and

damage of a much more permanent character. They do not pass away immediately, or in a day or two, but come "to stay," as it were, and to propagate their species. They are to be dreaded, therefore, not only for the damage they themselves caused, but quite as much, indeed a great deal more, for the damage which their progeny would be certain to cause, if some effectual measures could not be devised for the latter's destruction. It is fervently hoped that the arrangement devised by Mr. Lefroy will prove an effectual remedy of a permanent character.

DHANJISHA EDALJI,
Dewan, Rajpipla State.

Circular Order No. 3, *dated the* 8*th July* 1904, *to the Suba and to the Thanadars and other Taluka officers* (*also notified to the public.*)

Locusts.

From observations and investigations made by the Entomologist to the Government of India it appears that ordinarily—

(1) After heavy rain locusts may be expected to be found coupling.

(2) Within two days, and at the most within a week, after this, the female locusts begin to lay eggs.*

(3) Egg-laying will take place in soil soaked with water to a depth of three inches or more. The female locust digs into the surface of the soil and buries a portion of the body in it. In the hole thus formed the egg is laid.

(4) The eggs are held together in a mass, each mass being about three inches long. One thousand such masses weigh one seer and contain from 1 to 1½ lakh of eggs. A quantity of locusts, males and females weighing five seers, would be equivalent to (*i. e.*, capable of producing) a seer of eggs.

* This will generally be in the same place in which the locusts were found coupling.

(5) The holes in which eggs are laid are easily distinguishable. They are a little larger than a lead pencil in diameter and with loose soil thrown round the rim, as if a worm had brought up the soil. A little below the surface a smooth even surface is seen as if the hole were full of gum or some solidified liquid. The egg mass reaches almost up to the surface. So that although the finding out of the egg masses with a view to destroying them is a very difficult and troublesome job it is not impracticable.

2. The orders given in this office No. 31, dated 14th November 1903, for ploughing up lands with a view to destroying the eggs are now withdrawn.

3. The only means of escape from the ravages of the locust pest in the immediate future are—

(*a*) The catching and destruction of as many locusts as possible, whilst they are coupling, or before then so as to prevent them laying eggs and propagating their numbers.

(*b*) To try and find out eggs as shown in clause (4) of para. 1 above and destroy them.

(*c*) To carefully mark those places where the locusts are found coupling because it is in such places that egg-laying will take place. A proper record of such places should, therefore, be kept and hoppers looked for there, in order that it may be possible to destroy them as soon as possible after they have come out. These hoppers take some time before they acquire the power of flying. Till then they simply hop from place to place, and it is then, *i. e.*, before they are able to fly, that it is easiest to destroy them

4. Officers and ryots are to carefully bear the above in mind and to take energetic action accordingly. People should be made to understand that it is their duty to exert themselves to the utmost of their powers to free themselves from this great impending danger. If they deliberately fail to do

this it will not be possible for the State to show them any leniency (in the way of remissions, etc.). It is the duty of all village officers to carefully carry out the instructions given in clause (*c*) of para. 3 above. They should be informed that failure in this will be visited with very severe punishment. Carefully prepared lists of the places alluded to in the said clause should be kept and copies forwarded here through the Suba. Constant enquiries should be made at such places to ascertain whether the hoppers have come out of the eggs, and immediately this is found to be the case, effective steps should be taken for destroying them, immediate reports being submitted from time to time.

5. Rewards will be given for the destruction of locusts and of eggs at the following rates :—

	Rs.	A.	P
For a seer (lb.) of locusts ..	0	2	0*
„ „ „ eggs ..	0	10	0†

Thanadars of Talukas will disburse these rewards wherever they may be in their Talukas. Thanadars' Avalkarkuns will have the same powers at the Taluka head-quarters during the Thanadar's absence from there. The officer concerned should cause the eggs or locusts to be weighed in his presence before giving the reward.

6. Thanadars should, in the first instance, disburse the amounts of these rewards out of their ordinary permanent advances (of Rs. 100 each) and submit weekly bills for recouping the advance.

7. A register of rewards given should be kept in the following form. The principal register should be kept at the Taluka head-quarters, a supplementary register being kept by the Thanadar while on tour in the Taluka. At the end of every week the entries in the supplemental register should be copied into the head-quarters register with requisite explanations :—

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* Increased to Rs. 0-3-0 per lb.

† Increased to Re. 1-0-0 per. lb. by Circular No. 7, of 19th July 1904.

Form of register.

				Quantity brought.		Reward given.					REMARKS.
Current number.	Date.	Name.	Village.	Locusts (lbs.).	Eggs (lbs.).	For locusts.	For eggs.	Total.	Signature of payee.	Signature of officer before whom payment is made.	
1	2	3	4	5	6	7	8	9	10	11	12

Translation (in substance) of Circular No. 9, dated the 1st August 1904. (Rajpipla State).

The attention of all concerned is directed to—

Huzur Circular No. 2, dated the 8th July 1904.
Do. No. 4, dated the 14th Do.
Do. No. 7, dated the 19th Do.

2. These Circulars give orders concerning the measures to be adopted, and the rewards to be given for the destruction of—

(1) Locusts ;
(2) Locusts' eggs, and
(3) Hoppers.

3. As shown in the Circular Orders in question, the grown-up locusts die shortly after laying eggs, and most of them appear to have thus died off.

4. Notwithstanding the offer of a reward of one rupee per lb. of locusts' eggs, the quantities of eggs for which rewards have been claimed so far are insignificant ; and this is not surprising, as it is very difficult to get at these eggs. Moreover, the incubation period is five to six weeks and this much time has elapsed, or nearly elapsed, since the laying of eggs, in those

places in which there is reason to believe eggs were laid. So that in a short time hoppers will begin to come out of the eggs.

5. Much, thus, does not remain to be done in regard to grown-up locusts and eggs. But the rewards offered for both will be still continued.

6. But the great point which requires attention now is the destruction of the hoppers, which, as above, will soon be coming out of the eggs. As shown in previous Circular, these hoppers take some time before they are able to fly, and it is essential that any measures taken for their destruction should be taken before then. If this is not done, there is very little chance of any measures proving effectual after the hoppers have once acquired the power of flying. The hoppers will be able, *from the commencement*, to do much damage to the tender crops. As they grow, their power to do harm will increase, and, once able to fly, they will be able to accomplish the *wholesale and total destruction of crops*, however abundant the latter might be, and there is no measure which can prove effectual for the destruction of such flying locusts. There is only one remedy for preventing the terrible consequences above foreshadowed, and that is *to destroy these hoppers* before they acquire the power to fly. It is the duty of every cultivator to do everything in his power to accomplish this object. The Durbar will give all the assistance they can, but without the zealous and earnest co-operation of the people themselves, all endeavours will be futile. And it is hoped that the people will not fail to exert themselves to the utmost for protecting themselves against the terrible danger above referred to.

7. A very effectual remedy for destroying these hoppers has been devised by the Entomologist to the Government of India. A copy of the Circular issued by that officer is published with this. (Mr. Lefroy's mode of making and working the bag and frame or the bag and bamboo pieces is here fully explained.) A large bag and frame are sent as a specimen to each Taluka. In fields under crops, where the frame cannot work, the two pieces of bamboo sent with the bag should be used for keeping the mouth of the bag open. One such

bag and frame has been practically tested under the personal supervision of the Suba at a village of the Nandod Taluka, and the result has been highly satisfactory. All young grasshoppers and similar insects, as well as locusts' hoppers that there were in the field in which the experiment was made, were effectually caught in the bag, and it was impossible for any of them to escape by hopping out afterwards. Therefore, in every field in which the experiment is tried, it will be possible to destroy all hoppers that there may be in it.

8. The Thanadar of every Taluka should, in the first instance, as soon as he receives the bag and the frame sent as a specimen for his Taluka, practically test it in some field in the Taluka head-quarter station, and, after thus thoroughly understanding its working, should use it in another place in the presence of a large number of agriculturists. (Wherever damage is likely to be caused to the crops by using the frame, the bamboo pieces should be used.) Similar experiments should then be made in the other villages (where locusts had come and remained long enough to lay eggs) under the supervision of the Thanadar himself as far as possible, and of intelligent and zealous karkuns elsewhere. The people should then be instructed to work similarly in their own fields, and they should be made thoroughly and persistently to do this work. The bag and frame could be made by each individual for himself, inexpensively, out of any old cloth and pieces of bamboo, etc. Thus, with but little expense and with zealous work people will be able to ensure protection for themselves. Each agriculturist is bound, in his own interest, to do this work thoroughly and well, and it is the duty of all the Taluka and village officers to see, by exercising efficient supervision, that the people are not negligent in discharging this duty.

9. Each Taluka should, for this work, be divided into several parts, and each division placed under an energetic and intelligent karkun, the Thanadar himself supervising the work in the whole Taluka.

10. Each village should, similarly, be formed into a number of subdivisions, each such subdivision being placed under

one of the Patels or other leading man of the village. If there is a school in the village the services of the master and assistant should be availed of for this purpose. The man thus placed in charge of a subdivision should see the orders given in this circular thoroughly carried out in regard to each field in his division. If any agriculturist is found negligent, requisite steps should be taken through the Talati and Patel, and, failing result, report should be made to the Thanadar. Small waste strips round a field should also be dealt with by the owner of the field.

11. If in addition to the bags and frames sent out from here, it is necessary in any Taluka to have more bags and frames made at State expense, sanction should be applied for through the Suba. Or, if there is urgency, the things may be first made, and sanction to the expenditure incurred obtained subsequently.

12. Wherever it is not possible to make use of the bag and frame arrangement, use should be made of the long brooms with date or brab tree or khakhra leaves, referred to in para. 4 of Circular No. 4 for destroying the hoppers.

If the Thanadar needs the services of men other than his own subordinates he may, as above, utilize the school masters, and also the subordinates of the Police and Forest Departments employed in his Taluka, care being taken to see (with the co-operation of the superior officers of those departments) that the ordinary duties of these officials do not suffer. In addition to giving specific help in this manner, the subordinates of the Forest and Police Departments should, even while employed on their ordinary work, cordially co-operate with the revenue officials as far as they can in carrying out the objects of this order.

13. If the Thanadar considers that the adoption of any measures over and above those ordered by this Circular, would help to secure the desired end, he is authorised to take such steps also, but only as an addition to the action enjoined by these orders. If he finds any difficulty in working according to these orders, report should at once be made through the

Suba who, it is hoped, will personally exert himself with zeal to ensure the success of these measures.

14. If agriculturists are negligent in this matter, they are certain to be involved in great loss. They should be given distinctly to understand, however, that no leniency will be shown to them by the Durbar (in the matter of the collection of land revenue) for any losses which they may thus bring upon themselves.

15. The chief thing which State officials as well as the people have to bear in mind is, that if they sit still and do nothing under the belief that "nothing *can* be done in such matters," there is danger of the most serious loss to all. "Heaven helps those who help themselves," and if persistent and intelligent effort is zealously made, although it is possible that the measures taken may not prove completely successful, there cannot be the slightest question that they will ensure protection from damage to a very large extent.

APPENDIX D.

LOCALITIES FROM WHICH LOCUST REPORTS WITH SPECIMENS WERE RECEIVED, BOMBAY PRESIDENCY.

1	25th	September, 1903	Godhra, Panch Mahals.	Hoppers.
2	28th	,, ,,	Ahmedabad.	Locusts came from Amnagar.
3		October, ,,	Godhra, Panch Mahals.	Locusts.
4	2nd	,, ,,	Kaira.	Locust swarms.
5	3rd	,, ,,	Panch Mahals.	Locust swarms.
6	17th	,, ,,	Panch Mahals.	Locust swarms.
7	20th	,, ,,	Amalner, Khandeish	
8	25th	,, ,,	Yawal, Khandeish.	Eggs laid in May, by swarm from South.
9	26th	,, ,,	Bassein, Thana.	Also in October, 1902.
10	29th	,, ,,	Mandvi, Surat.	
11	2nd	November, ,,	Dholka, Ahmedabad.	
12	,,	,, ,,	Umargaon, Thana.	
13	10th	,, ,,	Bassein, Thana.	Went away.
14	11th	,, ,,	Raver, Khandeish.	Swarm produced from eggs laid in Bhusaval in June. Also came in 1901 and 1902.
15	11th	,, ,,	Mandvi, Surat.	Went to the South.
16	12th	,, ,,	Bulsar, Surat.	Swarm from the North.
17	14th	,, ,,	Chikhli, Surat.	Small swarms passing through.
18	28th	,, ,,	Bulsar, Surat.	Small swarms passing through.
19	28th	,, ,,	Salsette, Thana.	Passed through. Also in 1902.
20	1st	December, ,,	Jambusar, Broach.	Passed through.
21	12th	,, ,,	Belgaum.	
22	13th	January, 1904	Kolaba.	
23	13th	,, ,,	Pen, Kolaba.	
24	15th	,, ,,	Karjat.	
25	15th	,, ,,	Nagotna, Kolaba.	
26	20th	,, ,,	Murbad, Thana.	From Karjat to Kalyan and Shahpur.
27	20th	,, ,,	Roha, Kolaba.	
28	25th	,, ,,	Karjat, Kolaba.	
29	7th	March, ,,	Mahableshwar.	For weeks past.
30	,,	,, ,,	Poona.	
31	13th	,, ,,	Mokhada, Thana.	

32	22nd	March	1904	Khed, Ratnagiri.	
33	25th	,,	,,	Guhagar, Ratnagiri.	Swarm appeared.
34	27th	,,	,,	Thana.	Moving North to South.
35	28th	,,	,,	Fadgam, Ratnagiri.	
36	28th	,,	,,	Ratnagiri.	
37	28th	,,	,,	Salsette, Thana.	
38	29th	,,	,,	Dahanu, Thana.	
39	29th	,,	,,	Dapoli, Ratnagiri.	
40	29th	,,	,,	Mandangad, Ratnagiri.	Moving South-West.
41	31st	,,	,,	Shahapur, Thana.	Moving about since January.
42	31st	,,	,,	Murbad, Thana.	Came from Karjat and Junnar.
43	31st	,,	,,	Vada, Thana.	Moving North-West.
44	31st	,,	,,	Rajapur, Ratnagiri.	
45	1st	April	,,	Sangameshwar, Ratn.	
46	2nd	,,	,,	Bhiwandi, Thana.	Moving into Shahapur, Vada and Bassein.
47	4th	,,	,,	Ratnagiri.	
48	5th	,,	,,	Bassein, Thana.	Went to Mahim.
49	5th	,,	,,	Deogarh, Ratnagiri.	
50	8th	,,	,,	Umargaon, Thana.	Moved Northwards.
51	8th	,,	,,	Sangameshwar, Ratn.	
52	9th	,,	,,	Mahim, Thana.	Came from Bassein.
53	10th	,,	,,	Dahanu, Thana.	
54	11th	,,	,,	Chiplun, Ratn.	
55	11th	,,	,,	Rajapur, Ratn.	
56	11th	,,	,,	Ratnagiri.	
57	13th	,,	,,	Mahim, Thana.	
58	15th	,,	,,	Sangameshwar, Ratn.	
59	16th	,,	,,	Ratnagiri.	
60	19th	,,	,,	Dapoli, Ratnagiri.	
61	20th	,,	,,	Goa.	Appeared in 1901.
62	25th	,,	,,	Chiplun, Ratn.	
63	26th	,,	,,	Sangameshwar, Ratn.	
64	28th	,,	,,	Shahapur, Thana.	
65	28th	,,	,,	Bhimadi.	
66	29th	,,	,,	Rajpipla.	
67	2nd	May	,,	Ratnagiri.	
68	4th	,,	,,	Sangameshwar, Ratn.	
69	6th	,,	,,	Mandangarh, Ratn.	
70	7th	,,	,,	Shahapur, Thana.	
71	9th	,,	,,	Ratnagiri.	
72	9th	,,	,,	Umargaon, Thana.	
73	16th	,,	,,	Ratnagiri.	
74	18th	,,	,,	Jummar, Poona.	
75	18th	,,	,,	Chiplun, Ratn.	
76	19th	,,	,,	Shahapur, Thana.	
77	23rd	,,	,,	Junnar, Poona.	Remained here.
78	25th	,,	,,	Ratnagiri.	

79	27th	May	1904	Shahapur, Thana.	Remained here.
80	28th	„	„	Rajpipla.	Swarms from Mehwas, Khandeish.
81	6th	June	„	Murbad, Thana.	Remained here.
82	7th	„	„	Chota Udaipur.	Locusts appeared.
83	1st	August	„	Mandvi, Surat.	Locusts appeared.

Central Provinces and Berar.

1	22nd	June	1904	Buldana.	Immature, both sexes.
2	22nd	„	„	Amraoti.	Mature, both sexes.
3	24th	„	„	Basim.	
4	25th	„	„	Yeotmal.	Mature, both sexes.
5	28th	„	„	Akola.	Mature, both sexes.
6	29th	„	„	Ellichpur.	Coupling, both sexes.
7	8th	July	„	Buldana.	Mature, both sexes.
8	14th	„	„	Akola.	Mature, both sexes, some laid eggs.
9	21st	„	„	Betul.	Mature, both sexes.
10	22nd	„	„	Chindwara.	Mature, both sexes.
11	1st	August	„	Basim.	Eggs and hoppers.

LIST OF PLATES.

PLATE I.—Frontispiece. The Bombay Locust.

PLATE II.—Area infested in 1903-1904. The lightly shaded part in the North is the area from which the swarms emerged. The darkly shaded part is the area infested during the third period. The dotted line marks the approximate limits of the area covered during the fifth and sixth periods. Drawn by Hormusji Deboo.

PLATE III.—Reproductive system.

Fig. 1.—Diagram of abdomen of female locust—

(*a*) Alimentary canal; rectum.
(*b*) Genital aperture.
(*c*) Nerve ganglion.

The sebific gland is below the rectum.

Fig. 2.—External reproductive organs, closed.
,, 3.— ,, ,, ,, open.
,, 4.—The digging processes fully expanded.
,, 5.—Alimentary canal, showing cæca.
,, 6.—Ovary and sebific gland.
,, 7.—Diagram of abdomen of male locust showing position of testis behind the cæca.
Fig. 8.—Male reproductive system.
,, 9.— ,, ,, ,,

(*a*) Alimentary canal.
(*b*) Genital opening.

,, 10.—Portion of testis showing tubercles opening into vas deferens.

PLATE IV.—

Fig. 1.—Egg mass in the soil. x1.
,, 2.—Egg mass. x1.
,, 3.—Hopper, one day after hatching. x5.
,, 4.—Hopper, after first moult. x5.
,, 5.—Hopper, after second moult. x5.
,, 6.—Hopper, after third moult. x5.
,, 7.—Hopper, after fourth moult. x3.

PLATE V.—

Fig. 1.—Hopper, after fifth moult. x2.
„ 2.—Hopper, after sixth moult. x2.
„ 3.—Newly emerged locust. x1.

PLATE VI.—

Fig. 1.—Bag with vertical bamboos.
„ 2.—Collapsing bag with four bamboos.
„ 3.—The small bag without frame.

PLATE VII.—

Fig. 1.—Bag with bamboos ready for use.
„ 2.—Bamboo frame ready for bag.

PLATE VIII.—

Fig. 1.—Acridium succinctum. Linn.
„ 2.— „ peregrinum. Oliv.
„ 3.— „ æruginosum. Burm.
„ 4.—Hieroglyphus furcifer. Serv.

PLATE IX.—

Fig. 1.—Acridium succinctum. Linn.
„ 2.— „ peregrinum. Oliv.
„ 3.— „ æruginosum. Burm.
„ 4.—Locust in cylinder, for sending through post.

PLATE X.—

Fig. 1.—Acridium succinctum. L. male.
„ 2.— „ „ female.
„ 3.— „ peregrinum. Ol. male,
„ 4.— „ „ female.
„ 5.— „ æruginosum. Burm. male.
„ 6.— „ „ female.
„ 7.—Hieroglyphus furcifer. Serv. male.
„ 8.— „ „ female.

PLATE XI.—

Fig. 1-3.—Hoppers of *Acridium æruginosum.* Burm. x1.
„ 4.—The painted grasshopper, *Pœcilocerus pictus.* F.

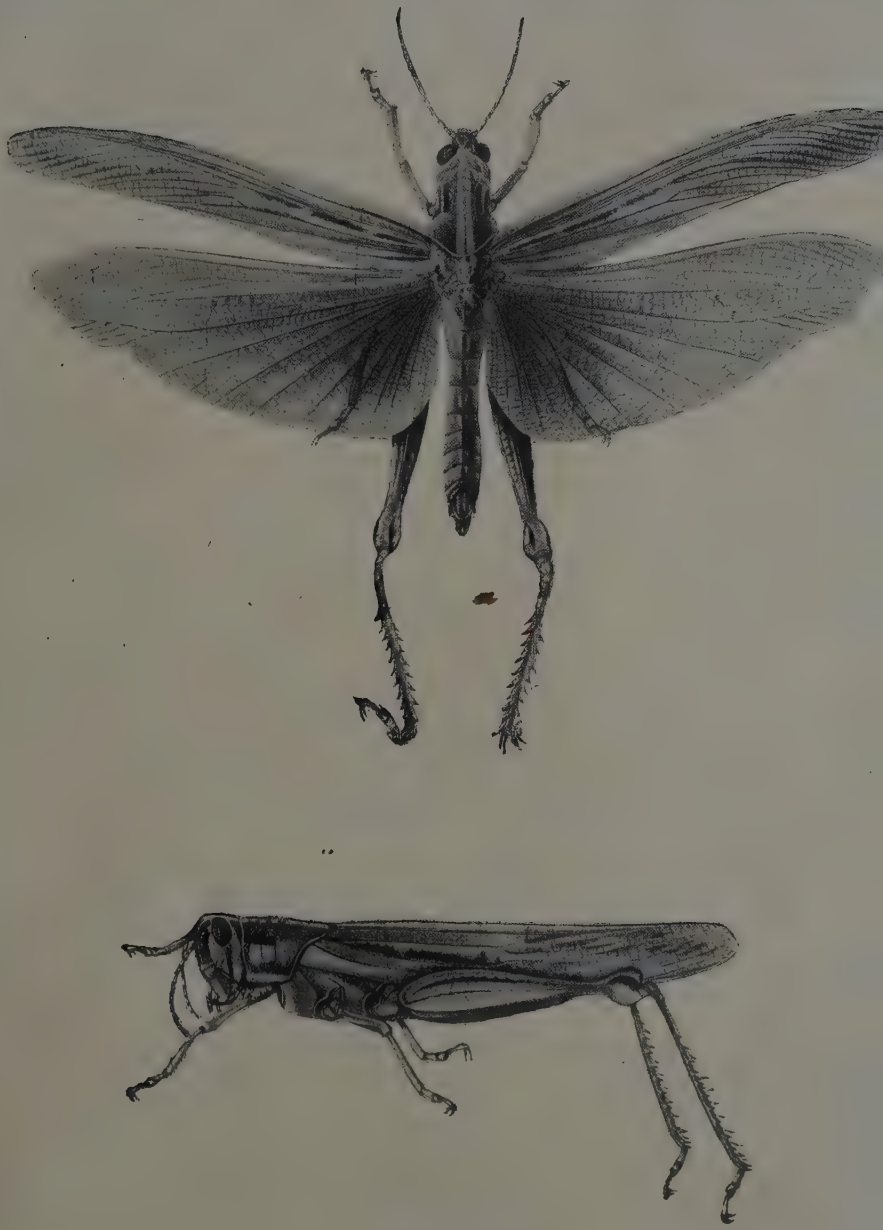
PLATE XII.—

Fig. 1.—Demodocus robustus.
„ 2.—*Acrida turrita.* Linn.
„ 3.—*Acridium melanocorne.* Serv.

PLATE XIII.—

Fig. 1.—Cage.
„ 2.—Hinged sides.
„ 3.—Batten top.

PLATE I.



Acridium Succinctum L.

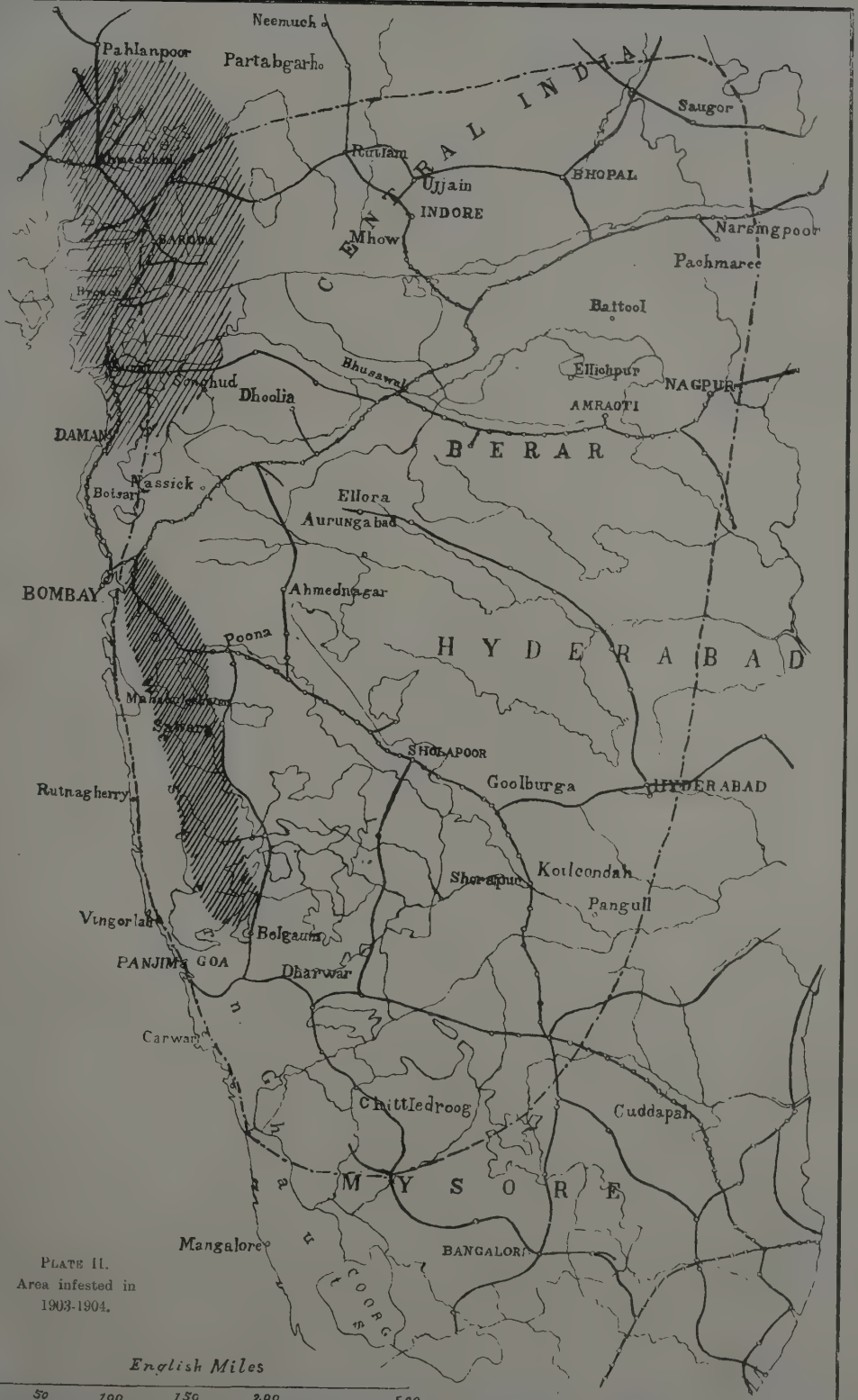
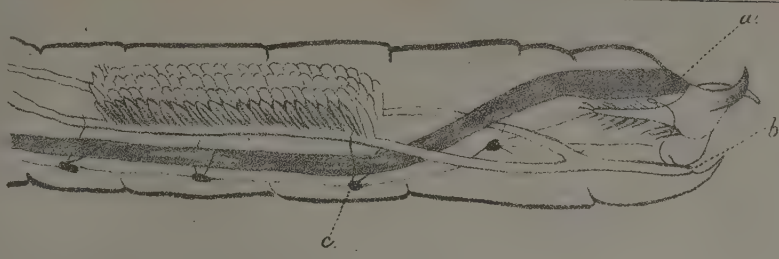
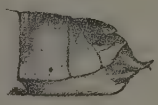


PLATE II.
Area infested in
1903-1904.



1.

2.



3.

4.

5.

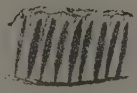
6.

7.

8.

9.

10.



H.M.L. del. A.Chowdhary, Lith.

REPRODUCTIVE SYSTEM.

PLATE IV.

Fig. 1.

Fig. 2.

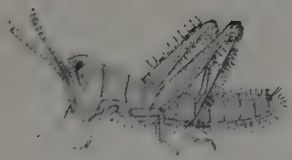


Fig. 3.

Fig. 4.

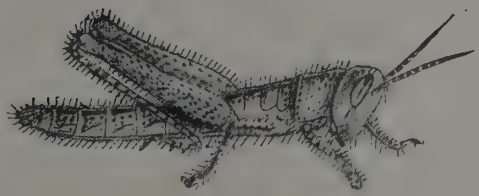


Fig. 5.

Fig. 6.

Fig. 7.

PLATE V.

FIG. 1.

FIG. 2.

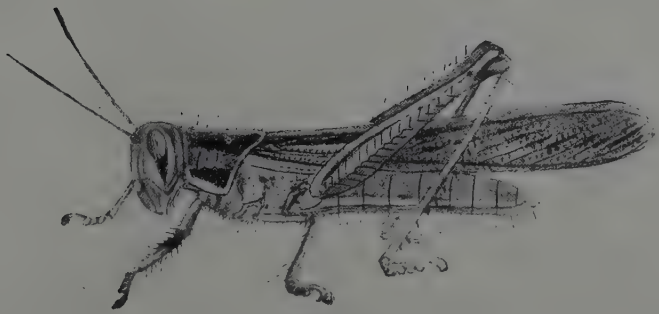


FIG. 3.

PLATE VI.

FIG. 1.

FIG. 2.

FIG. 3.

PLATE VII.

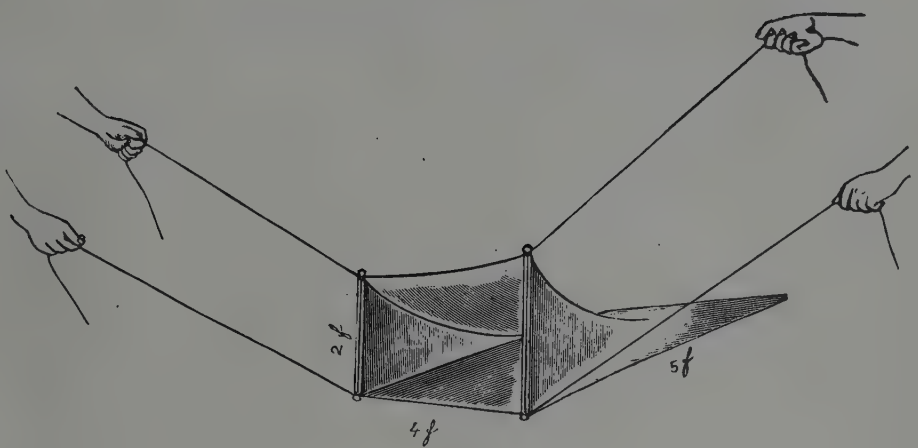


FIG. 1.

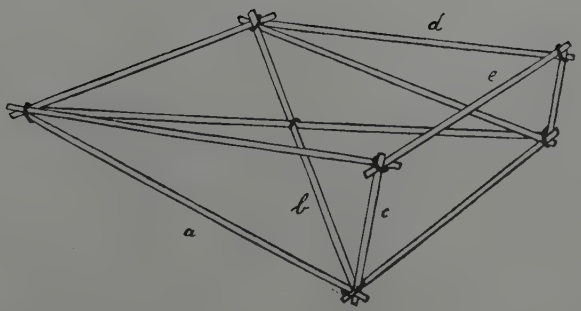


FIG. 2.

Fig. 1. Acridium succinctum, Linn.

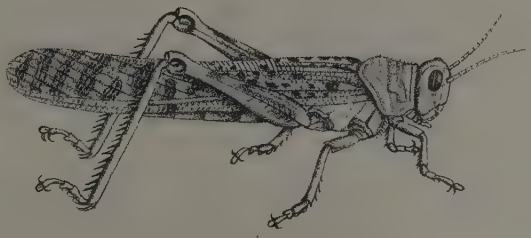


Fig. 2. Acridium peregrinum, Oliv.

Fig. 3. Acridium aeruginosum, Burm.

Fig. 4. Hieroglyphus furcifer, Serv.

H. Hormusji del. S. C. Mondul lith.

SIDE VIEW; NATURAL Size.

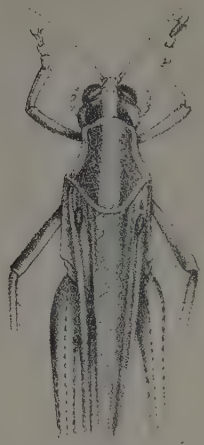


Fig. 1. Acridium succinctum, Linn.

Fig. 2. Acridium peregrinum, Oliv.

Fig. 3. Acridium aeruginosum, Sauss.

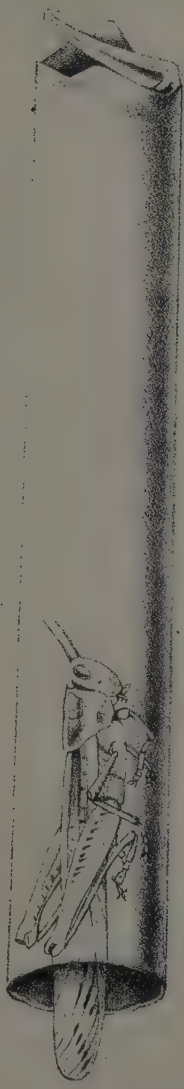


Fig. 4. Locust in Cylinder.

H. Hormusji del.

A. C. Chowdhary lith.

DORSAL VIEW OF THORAX

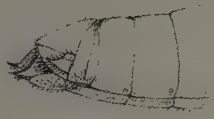


Fig. 1. ♀.

Fig. 2. ♂.

Acridium succinctum, Linn.

Fig. 3. ♀.

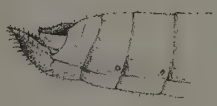


Fig. 4. ♂.

Acridium peregrinum, Oliv.

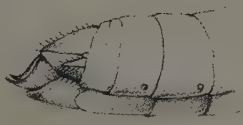


Fig. 5. ♀.

Fig. 6. ♂.

Acridium aeruginosum, Burm.

Fig. 7. ♀.

Fig. 8. ♂.

Hieroglyphus furcifer, Serv.

H. Hormusji del. A.C. Chowdhary lith.

SIDE VIEW OF ABDOMEN.
Natural Size.

PLATE XI.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

PLATE XII.

FIG. 1.

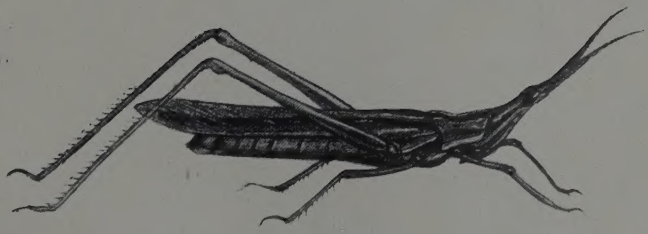


FIG. 2.

FIG. 3.

PLATE XIII.

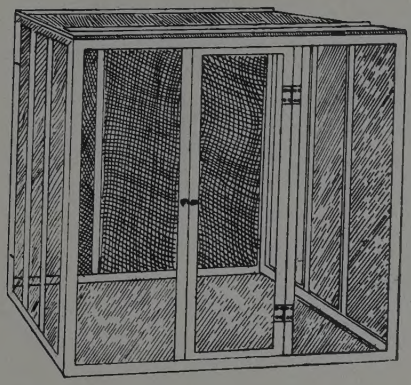


FIG. 1.

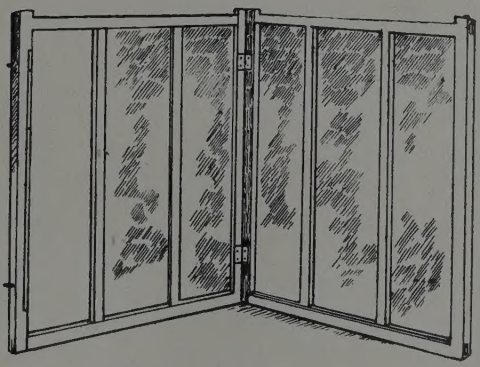


FIG. 2.

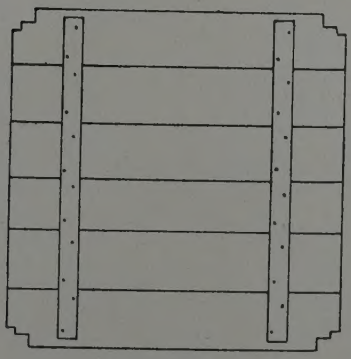


FIG. 3.